

The American Midland Naturalist

Devoted to Natural History, Primarily that of the Prairie States

Founded by J. A. Nieuwland, C. S. C.

Edited by Theodor Just

Contents

A Revision of the Mollusca of Indiana—Calvin Goodrich and Henry van der Schalie.....	257
New American Species of the Ostracod Genus <i>Entocythere</i> —C. Clayton Hoff.....	327
Helminths of Minnesota Canidae in Relation to Food Habits, and a Host List and Key to the Species Reported from North America—Arnold B. Erickson.....	358
The Harbor Seal in Washington State—Victor B. Scheffer and John W. Slipp.....	373
Observations on the Nesting Mortality of the Brewer Blackbird, <i>Euphagus cyanocephalus</i> —Ira La Rivers.....	417
Introduction to the Study of the Reptiles of Indiana—Sherman Minton, Jr.....	438
Notes on Amphibians and Reptiles from the Central United States—John C. Marr.....	478
Observations on the Life Cycle of the Common Newt in Western North Carolina—Claude S. Chadwick.....	491
Notes on Amphibians and Reptiles from Wisconsin—Richard A. Edgren, Jr.....	495
Food Habits and Molting of the Common Tree Frog—Harvey L. Sweetman.....	499
The Root System of Aspen—Maurice W. Day.....	502
Notes on <i>Navarretia abramsii</i> of the Polemoniaceae—Helen K. Sharsmith.....	510
Notes and Discussion	
Bibliographical Miscellany—V. Sara Allen Plummer Lemmon and her "Ferns of the Pacific Coast"—Joseph Ewan.....	513
Record of Alligator Juniper (<i>Juniperus pachyphloea</i> Torr.) on the Jornada Experimental Range, New Mexico—Arthur F. Halloran and Fred N. Ares.....	518
Book Reviews.....	519

EDITORIAL STAFF

THEODOR JUST.....	Botany
Editor, University of Notre Dame	
EDWARD A. CHAPIN.....	Entomology
U. S. National Museum, Washington, D. C.	
KENNETH W. COOPER.....	Cytology and Genetics
Princeton University, Princeton, New Jersey	
CARROLL LANE FENTON.....	Invertebrate Paleontology
Rutgers University, New Brunswick, N. J.	
JOHN HOBART HOSKINS.....	Paleobotany
University of Cincinnati, Cincinnati, Ohio	
REMINGTON KELLOGG.....	Mammalogy
U. S. National Museum, Washington, D. C.	
JEAN MYRON LINDSALE.....	Ornithology
Hastings Reservation, Monterey, California	
GEORGE WILLARD MARTIN.....	Mycology
State University of Iowa, Iowa City, Iowa	
KARL PATTERSON SCHMIDT.....	Ichthyology and Herpetology
Chicago Natural History Museum, Chicago, Illinois	
HARLEY JONES VAN CLEAVE.....	Invertebrate Zoology
University of Illinois, Urbana, Illinois	

NOTE: THE AMERICAN MIDLAND NATURALIST, published by the University of Notre Dame, is primarily, though not exclusively, devoted to the Natural History of the Middle West. A wide selection of papers on botany, paleontology and zoology is published in bi-monthly issues, three of which make up a volume.

Twenty-five reprints will be given free of charge provided, at least, an equal number is ordered. Authors are requested to submit carefully prepared manuscripts and to limit tables and illustrations as far as possible. Abstracts should accompany manuscripts.

The following numbers are out of print: vol. 1, (1, 3, 5, 8, 11, 12); vol. 2, (1-3, 8-10); vol. 3, all numbers; vol. 4, (1-9, 12); vol. 5, (6-8); vol. 6, (5, 8, 9, 12); vol. 7, (6); vol. 8, (7); vol. 9, (5-7, 9, 10); vol. 10, (8, 9); vol. 11, (1, 5-8, 12); vol. 12, (2, 10-12); vol. 13, (3, 4); vol. 14, (1-5, 7-9); vol. 15, all numbers; vol. 16, all numbers; vol. 17, (1, 2, 4, 5); vol. 18, all numbers; vol. 30, (1). Available issues of vols. 1-14, 30 cents per copy; complete volumes, \$3.00 each, except volumes 7, 13, and 14, \$1.50 each; vol. 15, \$2.00, single issues, 35 cents; vol. 16, \$3.00, single issues, 50 cents; vol. 17, \$4.50, part 1, \$2.00, nos. 2-6, 50 cents each; vol. 18, \$3.00; single issues, 50 cents; vols. 19-31, \$2.50 each; single issues, \$1.00. Subscription price per year, \$5.00.

Exchanges for journals, special volumes or duplicate books, and specimens should be arranged directly through the editorial office at the University of Notre Dame, where subscriptions also are received. Offers should accompany request for exchange.

For citation use this abbreviation: *Amer. Midl. Nat.*

The *American Midland Naturalist* is indexed in the INTERNATIONAL INDEX.

Entered as second-class matter at Notre Dame, Indiana. Acceptance for mailing at special rate of postage provided for in section 1103, Act of October 3, 1917, authorized on July 3, 1918.

ny
gy
cs
gy
ny
ty
ty
ty
ty
ty

of
4-
y
a
l
-
d

—

T

V

Ri
re
in
sh
Fa
be
sti
w
E
Fr
sp

tw
w
E
S
In
th
T
sc
sh
D
ex
p
K
to
bi
th
tu
A

S
of
P

The American Midland Naturalist

Published Bi-Monthly by The University of Notre Dame, Notre Dame, Indiana

VOL. 32

SEPTEMBER, 1944

NO. 2

A Revision of the Mollusca of Indiana

Calvin Goodrich and Henry van der Schalie

Constantine Smaltz Rafinesque mentioned Indiana once and the Wabash River three times in his writings on the mollusks of the trans-Appalachian region, and so must be considered the first of the naturalists to be interested in the shell-life of the state. No doubt he was frequently along the Indiana shores while he was searching the Ohio River for material, especially at the Falls, but in assigning so many of his finds to Kentucky he appears to have been quite aware that the political border line did not follow the center of the stream. The serious weakness of Rafinesque, as has been repeatedly recited, was the stark brevity of his descriptions. For example, in 1818 he defined *Elliptostoma gibbosa* as having "4 spires, a large knob behind the outward lip. From the Ohio and Wabash, length half an inch." What he meant has inspired ingenious guessing, but nothing better.

Trustworthy beginnings of the study of the subject were with Thomas Say, twice a traveler in the area and finally a resident. His first sight of Indiana was from a steamboat carrying him down the Ohio River with the Long's Expedition of 1819. While stops were made for fuel or provisions or repairs, Say went ashore, and as he did so in Ohio doubtless he made collections at Indiana landings also. On the second of the expeditions, in 1823, he came into the country overland through Wheeling and Columbus to Fort Wayne. Thence the journey was over the trail that struck the Great Sauk Trail in southwestern Michigan and branched off from this dim and soggy path to the shores of Lake Michigan and to Chicago, then commonly spoken of as Fort Dearborn. One or two species described or mentioned in the report on this expedition as found in the North-West Territory may have been taken in this part of the journey. Three years later, Say came with the "Boat-load of Knowledge" to the communal experiment of New Harmony, and here he was to remain through the varying periods of prosperity and depression, unity and bickerings, of the colony until his death. R. É. Call printed a list of twenty-three species of shells of Indiana which were named by Say, and this constituted only a small part of his work. Say has been put forth as the "Father of American Entomology." He was sire as well of molluscan studies in America.

In the period of accumulation of information on the zoology of the United States, disconnected and casual in the nature of things, numbers of mollusks of Indiana were described by J. G. Anthony, T. A. Conrad and Isaac Lea. Professor S. S. Haldeman dealt with certain shells which came to him from

Mrs. Say after the death of Thomas Say. Dr. John T. Plummer listed the forms occurring about Richmond in Wayne County. D. R. Moore and A. W. Butler made the same kind of examination in Franklin County and E. Pleas in Henry County. The first attempt to bring together data concerning the Mollusca of the whole state was by Fred Stein. This was published in the report of the State Geological Survey for 1880. A work carrying descriptions of species and embodying distribution was by Dr. R. E. Call. This was made a part of the report of the Indiana Department of Geology and Natural Resources for 1899. The paper is particularly valuable for the original plates which accompany it. Announced as a supplementary paper to this catalogue was one *On Some Mollusca Known to Occur in Indiana* by W. S. Blatchley and L. E. Daniels, issued in 1903. With it was *A Check List of Indiana Mollusca, with Localities*, a compilation by Daniels alone. It contains information about the fauna of northern Indiana, little of which had been known to Call. A report by Blatchley upon the Mollusca of Lake Maxinkuckee was expanded in *Lake Maxinkuckee, a Physical and Biological Survey*, B. W. Evermann and Howard W. Clark, 1920, volume 2, pages 41-75. There are evidences that in this production, certain mollusks not of the lake although of Indiana were included. *A Supplemental Check List of Indiana Mollusca* by Daniels followed his first compilation. Of later writers upon the general subject, A. C. Billups wrote about Mollusca in the vicinity of Lawrenceburg, A. A. Hinkley of findings in the lower Wabash River and Frank Collins Baker of those in Cedar and Bass lakes of north Indiana.

It can be taken for granted that the Mollusca of Indiana are entirely post-glacial. At least no species has been observed in the non-glaciated area of the state which can be considered as having occupied the region before the ice age and carried over into the post-glacial period. It is of interest in this connection that the same negative evidence obtains for the mollusks of the driftless section of Illinois, Wisconsin and Iowa. Means by which reinvasion was accomplished have received some speculative attention, the surmises, as they must be called, being based upon what is known of ways of distribution at present and the knowledge of ecological factors which appear to govern dispersal—a mass of somewhat chaotic material constantly undergoing revision. Some of the small land shells have been found in situations to which seemingly they could have been borne only by winds, some possibly as ova. Indications are that larger land forms have followed up the damp and wooded banks of streams by slow movement from molluscan generation to generation. Some of the Planorbidae, appearing even in temporary field and woods pools, in watering troughs and reservoirs, can be explained as distribution by birds. Living *Succinea*, as another example, have been discovered among the feathers of wildfowl. The extremely restricted oviposition in the Pleuroceridae is reflected in the fact that in this group there is no sign whatever of dissemination overland. Thus while streams of different drainage basins may very nearly approach one another, each occupied by pleurocerids, their fauna may be entirely distinct. In the case of the Unionidae, dispersion is linked with that of fishes upon which the glochidia are parasitic. Whatever the mode of distribution, it has to be remembered that continued existence of a mollusk in any

spot to which it may penetrate depends upon whether that spot is environmentally favorable, particularly for reproduction. It is to be suspected that in times without number migration has proved a failure.

That varying aquatic ecology is attended by a variation in molluscan populations is illustrated by the Pleuroceridae of the Wabash River. The names of the species upstream to downstream are here given:

Five miles w. of Celina, Mercer Co., Ohio	Mt. Carmel, Wabash Co., Illinois
<i>Goniobasis livescens</i>	<i>Pleurocera canaliculatum</i>
Bluffton, Wells Co., Indiana	<i>Lithasia obovata biconica</i>
<i>Goniobasis livescens</i>	<i>Lithasia armigera</i>
<i>Pleurocera acuta</i>	New Harmony, Posey Co., Indiana
Logansport, Cass Co.	<i>Pleurocera canaliculatum</i>
<i>Goniobasis livescens</i>	<i>Pleurocera canaliculatum undulatum</i>
<i>Pleurocera acuta</i>	<i>Pleurocera canaliculatum excuratum</i>
Lafayette, Tippecanoe Co.	<i>Lithasia obovata</i>
<i>Goniobasis livescens</i>	<i>Lithasia armigera</i>
<i>Pleurocera acuta</i>	<i>Lithasia verrucosa</i>
<i>Pleurocera canaliculatum</i>	Grand Chains, Posey County
Montezuma, Parke Co.	<i>Pleurocera canaliculatum</i>
<i>Pleurocera canaliculatum</i>	<i>Pleurocera canaliculatum undulatum</i>
<i>Pleurocera canaliculatum undulatum</i>	<i>Pleurocera alveare</i>
Vincennes, Knox Co.	<i>Lithasia obovata microlineata</i>
<i>Pleurocera canaliculatum</i>	<i>Lithasia armigera</i>
<i>Pleurocera canaliculatum undulatum</i>	<i>Lithasia verrucosa</i>
<i>Lithasia obovata</i>	<i>Anculosa praeciosa</i>

It will be seen by this list that Lafayette is a transition point, a situation in which conditions are favorable for both the upstream forms that may be called northern and forms representative more of the southern molluscan fauna. The southern aspect is most noticeable at the Grand Chains where all the Pleuroceridae are species that are common to Kentucky and Tennessee rather than to states north of the Ohio River, three occur in the Ohio River but make a northern invasion only into the Wabash River, and one is known only to the Wabash and a tributary of the Green River of Kentucky. (Species and subspecies are here treated of as on the same taxonomic plane.)

Adaptiveness varies among the Mollusca as among other organisms. Those species the remains of which are found in Pleistocene deposits were unquestionably very adaptive, and physiologically can be thought of as pioneers. Such of them as exist today display this quality by occupying a very wide range of habitats. Of more limited adaptiveness are those terrestrial species that live along the bluffs of the Ohio River and indicate no tendency to get beyond them. Examining the distributional data for Indiana, it is observed that twenty-four species of gastropods, terrestrial and freshwater, are restricted to counties on the Ohio River or close to it, that thirty-eight do not occur north of the broad bend of the Wabash, and that thirty-three, mostly of the order Pulmonata, appear (so far as information shows) to belong exclusively to the areas north of the bend.

The more recent papers on the Unionidae of Indiana have been concerned largely with the ecological conditions under which these mussels live and

which determine their distribution. T. J. Headlee (1906) wrote about the ecology of the mussels in Winona, Pike and Center lakes of Kosciusko County; C. B. Wilson and H. W. Clark (1912) in two separate papers reported on the mussel fauna of the Maumee and Kankakee rivers; B. W. Evermann and H. W. Clark (1918) discussed the "Unionidae of Lake Maxinkuckee"; W. R. Allen (1914, 1921, 1922, 1923) contributed several outstanding papers on the biology of mussels in Winona Lake; F. Wenninger (1921) and H. van der Schalie (1936) discussed the naiades of the St. Joseph River of north-western Indiana.

As a result of the stimulus given by the careful studies of the late Dr. A. E. Ortmann considerable information has accumulated regarding the succession of mussels throughout various drainage basins. Sufficient information has accumulated through the efforts of several malacologists within the last quarter century to indicate that this sequence in a stream follows a definite pattern. This order of succession apparently is established not only for mussels, but, as has been discussed previously, holds for many of the freshwater gastropods as well. It is interesting in this connection to find that a tabulation (see Table 1) of the mussels recorded for the Wabash River indicates that there is a definite and radical change in the species of naiades, as there is of pleurocerid gastropods, in the region of Lafayette. Unfortunately, the amount of material available for charting the distribution of the mussels in this stream is all too scant. The ranges of distribution within such a stream would be more exact and perhaps more striking if one could collect with just such a mapping program in mind. However, in taking the records from several sources there is more certainty that the resulting tabulation is based on facts and not on preconceived notions. The records are of collections made long enough ago to suggest that they may never be duplicated when we consider the changes that sewage and industrial wastes have brought about in the Wabash River.

It has been shown repeatedly that the number of species of both mussels and freshwater gastropods increases as one passes from the headwaters to the mouth of a river. The figures (Table 1) in the total column for the Wabash River drainage also indicate this numerical increase. However, at a point located somewhere near the center of the main stream in the region of juncture between what may be called small-river and large-river conditions, the total number of species is frequently surprisingly high. This observation is not generally emphasized although it is revealed repeatedly in distribution tables of individual drainage systems. Such a zone of transition with its great numerical increase of species is shown for the Wabash River (Table 1) where the number recorded for the region of Lafayette is forty-eight, only two less than that given for the lower river at New Harmony.

The tabulation of species recorded for the Wabash River (Table 1) suggests that the following four zones occur as delimited by the distribution of the mussels in that river:

1. Headwaters—covering roughly the main stream from Adams County through Cass County. This region usually produces in abundance the following species:

Alasmidonta marginata
Amblema costata
Anodonta grandis
Anodonta imbecillis
Anodontoides ferussacianus
Carunculina parva
Elliptio dilatatus
Fusconaia flava

Lampsilis fasciola
Lampsilis silquioidea
Lampsilis ventricosa
Lasmigona compressa
Lasmigona coslata
Micromya iris
Pleurobema cordatum coccineum
Strophitus rugosus

2. Zone of Transition—covers the area from Cass County to Warren County. The number of species is large because one often finds in the zone species common to the headwaters together with others classified with the next, or large-river region. No special list need be given for this section of the stream, but it should be emphasized that the number of species in any one locality is apt to be comparatively high. Actually forty-eight species have been listed from Lafayette, in Tippecanoe County. This is a composite of species listed for Zones 1 and 2.

3. Large River Zone—largely between Tippecanoe County and Posey County near the mouth of the Wabash. The following species are common to this region:

Actinonaias carinata
Amblema peruviana
Arcidens confragosus
Cyclonaias tuberculata granifera
Cyprogenia irrorata
Elliptio crassidens
Fusconaia ebenus
Fusconaia subrotunda
Fusconaia undata
Lampsilis anodontoides
Lampsilis ventricosa
Lasmigona complanata
Lastena lata
Leptodea fragilis
Leptodea leptodon
Ligumia recta latissima
Megalonaia gigantea

Obliquaria reflexa
Obovaria olivaria
Obovaria subrotunda
Obovaria retusa
Plagiola lineolata
Plethobasus cyphus
Pleurobema cordatum + catillus + pyramidatum
Proptera alata
Quadrula cylindrica
Quadrula metanevra
Quadrula nodulata
Quadrula pustulosa
Quadrula quadrula
Tritogonia verrucosa
Truncilla donaciformis
Truncilla truncata

4. Zone of Influx—from Grand Chains to the mouth of the stream. In this region several species, otherwise associated with the Ohio River and not typically a part of the Wabash drainage, invade the lower portion of the river. They are:

Cumberlandia monodonta
Dysnomia foliata
Dysnomia personata

Dysnomia sampsoni
Proptera capax
Simpsoniconcha ambigua

The above six species are found in addition to those listed in the previous zone as common to large-river conditions, bringing the total number in this region of the Wabash to fifty-two.

There is an increasing need for careful tabulations of species in the various drainage basins. Such information not only enables the zoologist to delimit the distribution of a species, but also aids greatly in accounting for the possible route taken by the animals in arriving at the places now found. It is knowledge of this kind that enables one to appreciate the importance of stream con-

TABLE 1.—Mussel Distribution in the Wabash River, Indiana

Species	Localities									
	Geneva—Adams Co.	Bluffton—Wells Co.	Peru—Miami Co.	Logansport—Cass Co.	Lafayette—Tippecanoe Co.	Independence—Warren Co.	Eugene—Fountain Co.	Montezuma—Parke Co.	Terre Haute—Vigo Co.	Merom—Sullivan Co.
1. <i>Actinonaias carinata</i>			x		x	x				
2. <i>Alasmodonta marginata</i>					x					
3. <i>Amblema costata</i>	x	x			x	x			x	
4. <i>Amblema peruviana</i>									x	
5. <i>Anodonta grandis</i>	x				x					x
6. <i>Anodonta imbecillis</i>		x			x					x
7. <i>Anodonta suborbiculata</i>										x
8. <i>Anodontoides ferussacianus</i>					x					
9. <i>Arcidens confragosus</i>									x	
10. <i>Carunculina glans</i>										x
11. <i>Carunculina parva</i>	x					x				x
12. <i>Cumberlandia monodonta</i>										x
13. <i>Cyclonaias tuberculata</i>				x	x				x	
14. <i>Cyclonaias tuberculata granifera</i>										x
15. <i>Cyprogenia irrorata</i>									x	
16. <i>Dysnomia flexuosa</i>										x
17. <i>Dysnomia perplexa rangiana</i>					x					
18. <i>Dysnomia personata</i>										x
19. <i>Dysnomia sampsoni</i>										x
20. <i>Dysnomia sulcata</i>					x					x
21. <i>Dysnomia torulosa</i>					x					x
22. <i>Elliptio crassidens</i>	x								x	
23. <i>Elliptio dilatatus</i>	x			x	x	x			x	
24. <i>Fusconaia ebenus</i>	x		x		x					x
25. <i>Fusconaia flava</i>					x					
26. <i>Fusconaia subrotunda</i>					x				x	
27. <i>Fusconaia undata</i>						x		x	x	
28. <i>Lampsilis anodontoides</i>						x				x
29. <i>Lampsilis anodontoides fallaciosa</i>					x				x	
30. <i>Lampsilis fasciola</i>					x				x	
31. <i>Lampsilis orbiculata</i>					x					
32. <i>Lampsilis ovata</i>					x					
33. <i>Lampsilis siliquioidea</i>	x		x		x				x	
34. <i>Lampsilis ventricosa</i>	x		x	x	x					x

TABLE 1. (Continued)—Mussel Distribution in the Wabash River, Indiana

Species	Localities												
	Geneva—Adams Co.	Bluffton—Wells Co.	Peru—Miami Co.	Logansport—Cass Co.	Lafayette—Tippecanoe Co.	Independence—Warren Co.	Eugene—Fountain Co.	Montezuma—Parke Co.	Terre Haute—Vigo Co.	Merom—Sullivan Co.	Vincennes—Knox Co.	Gibson Co.	New Harmony—Posey Co.
35. <i>Lasmigona complanata</i>	x		x		x				x		x		x
36. <i>Lasmigona compressa</i>					x								
37. <i>Lasmigona costata</i>	x		x		x				x				
38. <i>Lastena lata</i>					x								x
39. <i>Leptodea blatchleyi</i>													x
40. <i>Leptodea fragilis</i>				x	x	x			x		x		x
41. <i>Leptodea laevis</i>		x											x
42. <i>Leptodea leptodon</i>					x				x				x
43. <i>Ligumia recta latissima</i>				x	x								
44. <i>Megalonia gigantea</i>									x				x
45. <i>Micromya iris</i>					x				x				
46. <i>Obliquaria reflexa</i>		x			x				x				x
47. <i>Obovaria olivaria</i>					x				x		x		x
48. <i>Obovaria retusa</i>					x				x			x	x
49. <i>Obovaria subrotunda</i>					x	x		x	x				x
50. <i>Plagiola lineolata</i>					x				x				x
51. <i>Plethobasus cicatricosus</i>					x								
52. <i>Plethobasus cyphus</i>					x				x				x
53. <i>Pleurobema clavum</i>		x			x								
54. <i>Pleurobema cordatum</i>					x				x		x		x
55. <i>Pleurobema cordatum coccineum</i>	x	x		x	x				x				x
56. <i>Proptera alata</i>					x								x
57. <i>Proptera capax</i>													x
58. <i>Ptychobranthus fasciolaris</i>					x	x			x				
59. <i>Quadrula cylindrica</i>					x				x				x
60. <i>Quadrula metanevra</i>					x	x			x		x		x
61. <i>Quadrula nodulata</i>					x							x	x
62. <i>Quadrula pustulosa</i>				x	x	x			x	x		x	x
63. <i>Quadrula quadrula</i>		x				x							x
64. <i>Simpsoniconcha ambigua</i>													x
65. <i>Strophitus rugosus</i>				x	x	x		x	x				x
66. <i>Tritogonia verrucosa</i>					x				x				x
67. <i>Truncilla donaciformis</i>		x			x				x				x
68. <i>Truncilla truncata</i>					x				x		x	x	x
Totals	11	8	6	8	48	13	1	3	36	2	9	7	50

fluence in bringing the Mississippi River species common to the Maumee River, Lake Erie, and streams flowing into that lake, across the Wabash-Maumee divide. Aided by the related fields of glacial geology and geomorphology, it explains why species, such as *Lampsilis fasciola* and *Ptychobranchus fasciolaris* are found in northeastern Indiana, but are absent in the northwestern part of the state; or, vice versa, why *Actinonaias ellipsiformis* occurs in northwestern Indiana, but is not found in the northeastern portion.

Several names have been proposed and used for the two classes of mollusks represented in inland America, but none appears to improve upon the simple and familiar terms, univalves and bivalves. So after careful consideration, the writers of this paper have decided to employ these non-technical names.

KEY TO THE FAMILIES

Terrestrial Gastropods

1. Spiral shell covering body 2
 Body not covered by shell (rudimentary shell buried in tissues) 11
2. Shell without an operculum 3
 Shell with an operculum 10
3. Shell with a reflected lip 4
 Shell without a reflected lip, edge of aperture sharp 8
4. Shell large and dull, usually more than 5 mm. in diameter *Polygyridae* 5
 Shell small, about 3 mm. or less in diameter 5
5. Shell flattened or dome shaped, more or less widely umbilicate 6
 Shell with a high spire, usually imperforate 7
6. Lamellae present on parietal wall at base of last whorl *Strobilopsidae*
 No lamellae or teeth on base of last whorl *Valloniidae*
 Shell small (less than 6 mm. high), pupoid or oval in outline, often with a rounded aperture, about half as broad as high *Pupillidae*
 Shell minute (less than 6 mm. high), length about twice its width, aperture long and narrow with a single plate on parietal wall *Ellobiidae*
 Shell small (more than 6 mm. high), smooth, polished and shiny *Cochlicopidae*
 Shell large, dull and coarsely ribbed *Endodontidae*
 Shell thin, spiral, few rapidly expanding whorls, aperture very large *Succineidae*
 Shell surface shiny, usually polished and smooth 9
9. Spire more or less rounded, surface of shell vitreous, umbilicus small *Zonitidae*
 Spire flattened, surface not vitreous, umbilicus very wide *Haplotrematidae*
 Shell thick, dome-shaped, aperture closed with an operculum *Helicinidae*
 Animal without external shell
 Body long when extended, mantle anterior *Arionidae*
 Much smaller, mantle anterior, lobe-like *Limicidae*
 Mantle covering nearly the whole slug *Philomycidae*

Fresh-water Gastropods

1. Shell cap-shaped or patelliform *Ancylidae*
 Shell coiled or spiral, spire flat or attenuate 2
2. Shell without an operculum 3
 Shell with an operculum 4
3. Shell thin, dextrally coiled, spire more or less attenuate *Physidae*
 Shell thin, sinistrally coiled, spire more or less attenuate *Physidae*
 Shell thin, coiled in one plane or planorboid *Planorbidae*
 Shell thick, large (usually exceeding 6 mm. in height) 5
 Shell thick but small (usually less than 6 mm. in height) 6
5. Shell large, about as wide as high, few (5) well rounded swollen whorls producing an obtuse spire, aperture large and circular *Viviparidae*
 Shell large about twice or more higher than wide, with numerous flattened whorls producing an acute spire, aperture small and elliptical *Pleuroceridae*

6. Shell minute, operculum multispiral and circular, shell often but not always carinate *Valvatidae*
 Shell minute, operculum paucispiral and more or less elliptical *Amnicolidae*

Fresh-water Bivalves

1. Shell usually thin and small (not exceeding 1 cm. in length), beaks central, hinge teeth consisting of cardinal, as well as posterior and lateral, teeth *Sphaeriidae*
 Shell usually thick and large (exceeding 1 cm. in length), beaks or umbones located in anterior half, hinge with pseudocardinals and posterior laterals only *Unionidae* and *Margaritanidae*
 Shell elongate, arcuate, with well developed pseudocardinals but without laterals, epidermis black without rays. Gills without distinct, interlamellar septa *Margaritanidae*
 Shell variable, with or without hinge teeth. Gills with distinct, interlamellar septa *Unionidae*

Univalves

Family POLYGYRIDAE

A group of terrestrial, widely distributed snails, mostly ground-living, the genera distinguished from one another mainly upon differences in the reproductive organs. Shells resembling one another occur in different genera. The following key to forms in Indiana, based upon shell characters, is adapted from Pilsbry (1940):*

- Aperture small, umbilicus wide, no lip teeth but with teeth formed by a raised parietal callus. Indiana species are small ($\frac{1}{4}$ inch or less in diameter) *Polygyra*
 Aperture basal, narrow, with a long parietal tooth and often a notch in the basal lip; shell close-whorled, subglobose to lens-shaped. Indiana species small ($\frac{1}{4}$ inch or less in diameter) *Stenotrema*
 Aperture trilobed, with both parietal and basal teeth; umbilicate or imperforate: umbilicate species in Indiana medium size ($\frac{1}{2}$ inch in diameter). Imperforate species in Indiana large size ($\frac{3}{4}$ to 1 inch in diameter). *Triodopsis*
 Aperture with 0, 1 or 2 teeth.
 Depressed-globose to globose-conic, imperforate or with quite narrow umbilicus; toothless or with a small parietal or sometimes columellar teeth. Indiana species large ($\frac{3}{4}$ to 1 inch in diameter) *Mesodon*
 Depressed, widely umbilicate, aperture rounded; small obtuse tooth on basal edge. Indiana shell large (1 inch or more in diameter) *Allogona*

Genus POLYGYRA Say, 1818

Discoidal, thick, umbilicate, peristome continuous, aperture reflected and having a V-shaped parietal tooth; growth lines pronounced except on the nuclear whorls.

Polygyra leporina (Gould).—Spire slightly elevated, umbilicus partially

* For about forty years, all members of the Polygyridae were brought together under one generic name. A reclassification has been arranged by Dr. H. A. Pilsbry under which the family is split into several genera, a key to which is provided above. A key that would deal with the species necessarily lacks practicability for all students except those who have time and facilities for anatomical dissection. An illustration of the difficulties is the fact that the commonest Indiana form is outwardly *Mesodon*, but anatomically *Triodopsis*. For a key to what may be called *Polygyra* "old style," the reader is referred to F. C. Baker, *Field Book of Illinois Land Snails* (Urbana: Natural History Survey Division, 1939), pp. 41-43.

closed; outer lip notched with two small processes; parietal tooth joining the ends of the peristome. This is a southern species which in Indiana has penetrated as far north as Henry County. It lives in debris at the edges of woods. It was overlooked by Say at New Harmony, Posey County, but was found there by Daniels.

P. fatigiata Say.—Described in the New Harmony Disseminator of Useful Knowledge from local specimens. The shell is depressed, angled at the shoulder, roughly striate above and smooth on the base; aperture nearly closed by two strong processes on the inner edge of the outer lip and a stout parietal tooth. Known from Kentucky and Tennessee, and observed in Indiana so far only by Say.

P. plicata Say.—Coarsely striate on top, rounded at the periphery, the umbilicated base showing all the volutions; aperture with a strong V-shaped parietal tooth and two processes on the inside of the outer lip. A species of the south which was found in Indiana by Daniels "beneath drift on the north bank of the Ohio River, near Clarksville, Floyd County."

Genus STENOTREMA Rafinesque, 1819

Young usually hirsute, the shell lens-shaped as a rule, tightly coiled, imperforate; aperture constricted by a long parietal tooth and processes on the inner side of the reflected outer lip.

Stenotrema stenotrema (Pfeiffer).—Globose, imperforate; the parietal tooth curving, inner part of the reflected outer lip having a small notch; hirsute or showing papillose scars. Common in southern Indiana in debris of flood plains, the northern limit of distribution in the state apparently being Tippecanoe County. Indiana was named as the type locality. *S. maxilata* Gould, reported by Pleas as occurring in Henry County, is probably this species.

S. hirsutum (Say).—Smaller than most examples of *S. stenotrema* and more depressed; surface hirsute or granulose, parietal tooth sinuous, basal part of outer lip notched, a projection or process in the lip opposite the parietal tooth. The species occurs probably in all Indiana counties.

S. monodon (Rackett).—Spire low, base somewhat flattened, the shell umbilicate. The species has a strong parietal tooth. The outer lip has neither notches nor tooth-like processes. Commonly an inhabitant of low, damp grounds, sometimes in large colonies. Known to occur from La Porte to Posey counties and east to Allen County, and so probably is in every other county of the state.

S. fraternum (Say).—Resembles *S. monodon*, but is commonly imperforate or with only slight umbilical opening; usually larger, the spire higher. More often an inhabitant of uplands, living under logs and sticks, preferably in damp places. Adults tend to be solitary. The species is probably in all counties of the state. A larger, more depressed shell, "deeply impressed or excavated around the umbilicus," is subspecies *cavum* (Pilsbry and Vanatta). It is reported from Posey and Marion counties.

Genus MESODON Rafinesque, 1821

The genus consists mostly of relatively large snails, yellow to reddish-brown, thin to thick; the outer lip more or less broadly reflected; umbilicate or imperforate. The snails are inhabitants of ground situations although occasionally in wet weather they climb trunks of trees for a few feet.

Mesodon thyroideus (Say).—Globose to depressed-globose, whorls apparently never more than six; umbilicus partly covered. The species feeds on mildews, slime molds and fungi. Although a forest snail, the species has adapted itself to life in open fields and gardens, and under boards of factory yards. It occurs throughout Indiana and in every likelihood is the commonest member of the genus in the state.

M. clausus (Say).—Small compared with *M. thyroideus*, thin, striate, narrowly umbilicate, whorls five to six. It has adapted itself to life on old railroad embankments and among weeds of ditches. Probably in all counties of Indiana.

M. mitchellianus (Lea).—Like *M. clausus*, but somewhat differently shaped and with a closed umbilicus. It was reported by Daniels as from Brookville, Franklin County, but it is also known to occur in Dearborn, Floyd, Fayette and Jackson counties.

M. zaletus (Binney).—High in proportion to diameter, yellow to yellow-brown, imperforate, whorls about five and a half; a tooth-like process on the parietal wall. This is the *Polygyra eroleta* of Daniels' first list, in which it is reported as "common over the southern two-thirds of the State." This may be extended to damp unpastured woods and shaded sides of ravines in the northern counties.

M. pennsylvanicus (Green).—Suggesting *M. clausus* in shape and size, but the spire is more nearly acute; shell rather thick, dark brown, imperforate, the reflection of the outer lip narrow. The species lives in small numbers under logs and in debris which sometimes are in quite open spaces. It is known from Franklin, Marion, Vermillion, Martin, Clark, Washington, Lawrence, Knox and Gibson counties.

M. elevatus (Say).—Thick, globose-conic, strongly striate axially; aperture with a strong tooth on the parietal wall. Reported by Daniels as from all over the state, but it is absent in parts of northern Indiana. It lives commonly on the steep banks of streams and apparently has received distribution downstream by flood waters. The snail has the habit of burying itself in the ground through hours of strong sunlight and in periods of drought. A form with a band of pigment at the periphery lives in southern states and possibly inhabits counties of Indiana bordering the Ohio River.

M. appressus (Say).—Discoidal, low-spired, yellow to brown; umbilicus closed, outer lip somewhat broadly reflected. A white, elongate tooth is on the parietal wall. The habitat is among stones and vegetation of damp, limestone bluffs, the food seemingly lichenous. It is commonest in counties bordering the Ohio River, but is known also to be in Marion, Vermillion and Clark counties.

M. infectus (Say).—Small, lens-like, the base rounded and imperforate;

a long curving parietal process; a deep notch, projecting at the outer edges, in the outer lip. It lives among fallen leaves and in forest debris of ravine banks which often are almost arid. It has also been observed on nearly bare limestone bluffs. Daniels reported it "abundant in all parts of Indiana."

Genus TRIODOPSIS Rafinesque, 1819

Shells varying from globose to discoidal, the aperture with or without denticles; umbilicate to imperforate. While the exo-skeletons of some of the species are in general of striking dissimilarity, and on that ground may seem to belong to other genera, the genitalia are alike. Habitats range from damp, heavily forested areas to dry sides of ravines.

Triodopsis tridentata (Say).—Disc-shaped, the umbilicus wide, the reflected outer lip having two dentate processes on the inner side. On the parietal wall is a strong curving tooth. Number of whorls five to six. Call illustrated a form from North Vernon, Jennings County, which is about half the size of the common mollusk. The species occurs throughout the state, but more rarely in northern counties than in southern.

T. tridentata juxtidentis (Pilsbry).—Differs principally from the typical form in the positions of the teeth. Specimens taken near Bluffton, Wells County, have been identified as this race.

T. tridentata discoidea (Pilsbry).—Somewhat like the preceding subspecies, but more widely umbilicate and with such feeble growth lines as sometimes to appear smooth and shining. Confined in Indiana to areas bordering the Ohio River.

T. fraudulentula vulgata Pilsbry.—In shape, like *T. tridentata*, but with strongly developed teeth which narrow the aperture to small space, the outer lip "dished." This is a middle western form of a species of mountainous Virginia and West Virginia. It lives mostly under fallen leaves of partly shaded places, and seemingly can endure arid conditions and relatively high temperatures. Distributed throughout the state, but is more common in the northern half than in the southern.

T. notata (Deshayes).—Listed as *Polygyra palliata* (Say) in early compilations. The shell is flat, very wide compared with height, imperforate; the reflected lip broad and with a wide notch; the parietal tooth broad and curving. The epidermis is studded with coarse papillae that are often absent in very old individuals. It is to be found beneath logs in wet ground, seldom in numbers. Daniels reported it as "all over the state."

T. obstricta (Say).—Mainly distinguishable from *T. notata* in having a carinate or partially carinate periphery, and gradations with this species were found by Daniels in Posey County. Known in Indiana from no other county.

T. fosteri (F. C. Baker).—Like *Mesodon appressus* in general appearances, but having the soft parts of true *Triodopsis*. An inhabitant of limestone bluffs along the Ohio River, and observed in Indiana at Evansville.

T. albolabris (Say).—Large, *Mesodon*-like, imperforate, sometimes with a

low tooth on the parietal wall. The species varies greatly in size and proportions, the smallest individuals living in grasslands or in sandy areas in which moisture disappears early in the summer season. The species shows indications of adaptiveness to conditions brought about by deforestation. Distributed throughout the state.

T. multilineata (Say).—The shell is imperforate, globose to depressed-globose, the outer lip narrowly reflected. The principal distinguishing character is a series of revolving highly pigmented lines of varying width. It is an inhabitant of wet woods and the borders of marshes. During the hibernating period, it buries itself in the soil or among the rotting leaves of marsh plants, and in such places as many as a hundred individuals have been found closely packed together. In occasional specimens the bands are coalescent, giving the shell a distinct reddish appearance; in other, the pigmentation is entirely absent. To one the name of *rubra* has been given; to the second phase, *alba*. A small form, *algonquinensis* Mason, was observed by Daniels in Marshall County.

Genus ALLOGONA Pilsbry, 1939

Large, umbilicate, usually rather thick, depressed-globose, aperture rounded and reflected; the base of the lip with a small projection. Revolving lines of pigment make the shell conspicuous, but they are sometimes absent and usually have lost their brightness in old specimens. The genus was erected on the basis of peculiarities in the reproductive organs. Only one species occurs in Indiana.

Allogona profunda (Say).—The shell came to Say's notice while he was with the Long's Expedition, one of the localities he mentioned being the Ohio River banks. The species lives in deep woods and upon shaded limestone bluffs throughout Indiana. As it has been seen in marshy areas bordering the western end of Lake Erie it may be expected also to occur in similar situations along the southern loop of Lake Michigan.

Family HAPLOTREMATIDAE

Shell discoid, umbilicate, milky-white, or waxy-white in the case of the one middle western species. Animal slender when extended, with long eye stalks and short tentacles. The shell is borne posteriorly.

Genus HAPLOTREMA Ancy, 1881

The shell resembles that of some of the Zonitidae in being flattish, widely umbilicate and having an unreflected outer lip. Peculiarities of the radula are supposed to point to a very ancient development of a carnivorous feeding habit.

Haplotrema concavum (Say).—The species has appeared in earlier writings under the generic names of *Helix*, *Selenites* and *Circinaria*. It lives all over Indiana at the edges of woods and shaded margins of marshes, on limestone bluffs and occasionally in grass heaps in town gardens. F. C. Baker noted that shells of southern Illinois were larger than those of the northern

part of the state, and this appears to be true also in Indiana. The preying which the snail does on other land mollusca is probably not an exclusive feeding practice inasmuch as individuals have been found in situations harboring no other snails.

Family ZONITIDAE

Mollusks of this family are of many genera and species, world-wide in distribution. Anatomically those of Indiana can be separated as to whether they have a dart-sack or not. The following table is roughly a guide to genera according to shell characters:

1. Comparable in size with large Polygyridae	2
Six to twelve millimeters in diameter	3
Minute, less than six millimeters in diameter	4
2. Brown, shining, widely to narrowly umbilicate	<i>Mesomphix</i>
3. About half as high as wide, yellow, umbilicate	<i>Oxychilus</i>
a. Spire elevated, surface striate, callus on base	(<i>Ventridens</i>)
aa. Subglobose, callus on base; with internal teeth	<i>Gastrodonta</i>
4. Discoidal, shining, with axial striae; umbilicate or imperforate	<i>Retinella</i>
a. Whorls rounded, sutures deep, umbilicate, yellow to brown	<i>Zonitoides</i>
aa. Body whorl expanded, surface ribbed, pale	<i>Striatura</i>
aaa. Tightly coiled, umbilicate, amber colored	<i>Paravitrea</i>
aaaa. Spire low, whorls four, umbilicate, white	<i>Hawaia</i>
aaaaa. About as high as wide, tightly-coiled, yellow	<i>Euconulus</i>

Genus MESOMPHIX, Rafinesque, Beck, 1837

Soft parts are blue-black, the eye stalks short and well separated. The base of the foot is gray or white, a furrow upon the sides. At the rounded extremity is a mucous pore.

Mesomphix cupreus Rafinesque.—Large, thin, depressed, dark brown and shining; whorls nearly five, widely umbilicate. This snail is to be found among fallen leaves and other forest debris where the ground is deeply shaded or kept moist by proximity to streams. Call and Daniels observed the species only in the southern part of the state, but it occurs also in northern counties.

M. friabilis (W. G. Binney).—Large, more elevated than *M. cupreus*, umbilicate, thin, brown or reddish. Call said he had not seen Indiana specimens, and Daniels reported it from a cypress swamp in Knox County; Posey, Jackson and Crawford counties. Other localities for it are Marion, Gibson, Jefferson and Carroll counties.

M. perlaevus vulgatus H. B. Baker.—Convex, greenish, the umbilicus nearly closed. Noted by Moore and Butler in Franklin County; by Daniels in Perry, Jackson, Jefferson, Crawford and Clark counties, and by Billups in Dearborn County.

M. inornata (Say).—Smooth, somewhat depressed, umbilicus very much contracted. Found in counties bordering on the Ohio River.

Genus RETINELLA Shuttleworth, 1877

A group of very small shells which are depressed, umbilicate or imperforate and marked with axial striae. The blue-black color of the animal becomes

paler at the edges and the posterior extremity, which lacks a mucous pore.

Retinella indentata (Say).—So named by Say for the peculiarly pitted base, the opening very nearly closed. Over the surface are equally spaced impressed lines. It occurs throughout Indiana under logs and forest waste and in flood plains, usually in small numbers in any one place.

R. electrina (Gould).—Umbilicate, axially striate, dark; whorls four. Fresh specimens reflect light as though polished. Common under sticks, logs and leaves at the margins of woods, in debris close to marshes; sometimes in gardens and greenhouses. Probably everywhere in the state.

R. wheatleyi (Bland).—Much like the preceding, but with a greatly expanded final whorl. Recorded in Indiana as from Posey, Franklin, Marion and Dubois counties.

R. rhoadsi (Pilsbry).—Resembles *R. indentata*, but is widely umbilicate; it has also similarities in choice of habitats. Examples have not been seen from Indiana, but as the species has been found in Ohio, Illinois and Michigan it doubtless occurs in the state.

Genus HAWAIIA Gude, 1911

Seldom of greater diameter than three millimeters, waxy to chalky white, whorls four; aperture rounded, all volutions seen in the wide umbilicus.

Hawaiiia minuscula (Binney).—Common throughout the state under logs, sticks and stones, in clumps of grass, flood plain debris and gardens. Often more examples of the species appear in stream drift than any other mollusk.

Genus PARAVITREA Pilsbry, 1898

Distinguished from other Zonitidae by peculiarities of the radula. Shells of all the species are small, varying from one another in shape, sculpture and arrangement of denticles.

Paravitrea multidentata (W. G. Binney).—Very small, umbilicate, upper surface flattened, whorls six. Two or more rows of denticles radiate on the base from the umbilicus. Specimens in the Daniels collection are assigned to Wills Township, La Porte County.

P. capsella (Gould).—About half as high as wide, whorls six, the epidermis marked with impressed lines; umbilicate. Found by Daniels in Posey, Knox and Dubois counties.

P. significans (Bland).—Similar to *capsella* in size and shape, but with a higher spire and small interior denticles which in fresh material show through the translucent shell. So far this species has not been observed in Indiana, but as it occurs in southern Illinois it should also be in counties of this state bordering the Ohio River.

Genus EUCONULUS Reinhardt, 1883

Very small, conic, smooth, shining, yellow to brown. Animal mostly black, somewhat lighter in color on the side and bottom of foot. Extended, it appears to be disproportionately narrow.

Euconulus fulvus (Müller).—Rarely more than four millimeters in diameter or three in height. It is fairly common in low woods and in the trash of flood plains throughout the state.

E. chersinus (Say).—Of more whorls than *E. fulvus*, the angulation of the juvenile whorls disappearing in the adult stage; occasionally dentate. Known from western and northern counties of Indiana. A subspecies, *polygyratus* (Pilsbry) is more blunt of spire and has a more narrow aperture than the typical form. Found near Bass Lake, Starke County.

Genus STRIATURA Morse, 1864

Very small, the shells with fine, projecting ribs.

Striatura milium (Morse).—Flattened, greenish-white, the axial growth lines crossed by revolving lines that usually are microscopic. Daniels reported the species as from Princeton, Gibson County, and specimens are in his collection labelled as from La Porte County. A southern form, subspecies *meridionalis* (Pilsbry and Ferriss), has been found in southern Illinois, and is probably also in southern Indiana.

S. exigua (Stimpson).—Much larger than the foregoing and somewhat resembling *Vallonia costata*, but darker in color and without a reflection of the outer lip. The most striking character is a series of ribs which cross the growth lines obliquely. The mollusk has not been seen in Indiana yet, but is probably in the state inasmuch as it occurs in neighboring Ohio and Michigan.

Genus OXYCHILUS Fitzinger, 1833

Spire low, diameter ten to twelve millimeters, vitreous and yellow to brown. Two or three Old World species of this genus have become established in the United States.

Oxychilus cellarium (Müller).—The shell conforms to the above description. The animal is black above, becoming paler posteriorly. Extended, it is long and narrow. Daniels found the mollusk in a greenhouse at La Porte.

Genus GASTRODONTA Albers, 1850

Yellow, subglobose, the translucent shell showing a white deposit of callus on the inner side of the basal whorl; the aperture partially closed by strong denticles.

Gastrodonta interna (Say).—The original specimens were from "Lower Missouri," but in a few places the species occurs on the northern side of the Ohio River. It has been found in Indiana at Wyandotte, Crawford County; Madison, Jefferson County; New Albany, Floyd County; and Cannelton, Perry County.

Genus ZONITOIDES Lehmann, 1862

Shells of this genus vary from conic to flat, striate to smooth. Members of the subgenus *Ventridens* were formerly placed under *Gastrodonta*, but were found by H. B. Baker to be anatomically identical with *Zonitoides*.

Zonitoides (Ventridens) ligerus (Say).—Pyramidal, many-whorled, the upper part having coarse, axial sculpture, the base smooth and with a white or yellowish thickening. Common in debris of forests and flood plains, sometimes under stones. Colonies usually large. The species occurs throughout Indiana. A greenish form, *Z. ligerus sagdinoides* (Gratacap), has been credited to Indiana.

Z. (Ventridens) intertextus (Binney).—Very like *Z. ligerus*, but larger, coarser, occasionally with a narrow color band; the umbilicus small. Apparently confined in Indiana to southern counties.

Z. (Ventridens) demissus (Binney).—Smaller and more depressed than *Z. ligerus*, whorls about seven. The head of the animal is blue rather than black. Known from Lake County, but in every likelihood is widely distributed in the state.

Z. (Ventridens) gularis (Say).—Subglobose, yellow, a whitish deposit on the base. Within the aperture are to be seen small lamellar denticles. Not reported by Call, Moore and Butler, but found by Daniels near New Albany, Floyd County.

Z. arboreus (Say).—Small, thin, rather deeply sutured, umbilicate. The animal is grayish-black. This appears to have been the second mollusk for which Say undertook description. It is probably the most common snail in eastern North America, and is to be found under logs and bark, in decaying vegetation and often at the margins of city sidewalks. It is distributed throughout Indiana.

Z. nitidus (Müller).—Larger than *Z. arboreus*, the animal quite black. It lives on the banks of lakes, ponds and streams, and frequently at edges of marshes subject to inundation. Throughout the state.

Z. limatulus (Ward, Binney).—Characterized by strong, file-like sculpture; the umbilicus wide and showing all whorls. The species is seemingly restricted to an oak-hickory habitat and deeply shaded limestone bluffs. It was observed by Call near Wabash, Terre Haute and Indianapolis; by Daniels at Seymour and Indianapolis. Other known Indiana localities are Dearborn, La Porte, Parke, Jackson and Henry counties.

Z. laeviusculus Sterki.—Very small, glassy and colorless, umbilicate. In Indiana, it is known only from Dunreith, Henry County.

Family ENDODONTIDAE

Shells of all species of this family which occur in Indiana are roughly striate except one, have a simple unreflected outer lip and are umbilicate. Size ranges from minute to more than an inch in diameter. Upper part of animal darker than the foot. Eye-stalks long and slender, tentacles about one-fourth as long. This guide to the four genera of the area has been adapted from F. C. Baker (1939):

1. Shell relatively large, elevated or depressed, umbilicate; surface marked with
flamules or revolving bands *Anguispira*
2. Much smaller than 1, strongly striate, umbilicate, reddish brown..... *Discus*
3. Planospiral, spirally striate, toothed with aperture, waxy white..... *Helicodiscus*
4. Minute, subdiscoidal, umbilicate; with both riblets and revolving striae, reddish....
..... *Punctum*

Genus *ANGUISPIRA* Morse, 1864

The genus in the northern middle west is made up of two species, and in earlier writings has been known as *Helix*, *Patula* or *Pyramidula*. Some individuals are as large as the largest Polygyridae of the region.

Anguispira alternata (Say).—Usually depressed, but sometimes nearly as high as wide. Spots of dark pigment are arranged in rows, though occasionally absent. From a restriction mostly to forest, the species has come to live under boards, cement blocks, in gardens, dump heaps and fence corners. It is to be found in all Indiana areas. Pleas lists a variety *carinata* for Henry County. This is a form of the Cumberland Plateau and is probably not in the state.

A. kochi (Pfeiffer).—Robust, elevated, deeply and broadly umbilicate, usually with two dark stripes. Among shells taken in Spring Mill State Park, Lawrence County, are individuals in which the ground color is dark purple, the bands yellowish. This is a forest snail which apparently is in course of extinction, its colonies on shaded slopes and limestone bluffs becoming fewer and fewer. It was known until recently as *A. solitaria* (Say).

Genus *DISCUS* Fitzinger, 1833

Shells small, depressed, umbilicate, reddish-brown, and with strong vertical ribs. Animals nearly black on the upper surface, lighter below.

Discus cronkhitei anthonyi (Pilsbry).—This is the *Pyramidula striatella* (Anthony) of early lists. The small, striate mollusks occur often in great numbers in association with other snails living on the under sides of logs and in forest and flood plain debris. Doubtless in every Indiana county. Albino specimens are encountered now and then.

D. patulus (Deshayes).—This is the *Pyramidula perspectiva* (Say), the first specimens of which were brought to Say by Lesueur from the vicinity of Lake Erie. "Umbilicus very large, resembling an inverted spire . . . and exhibiting all the volutions. Diameter three quarters of an inch." It is commonly to be found under logs and starting bark, sometimes in the dust of rotting wood. Daniels lists it as "all over the state."

Genus *HELICODISCUS* Morse, 1864

Small, planospiral, grayish to yellowish white; sculptured with raised revolving lines. One to three denticles can be seen just within the aperture. There is only one species in Indiana.

Helicodiscus parallelus (Say).—Whorls four, coiled almost in the same plane. The animal is nearly colorless except for irregular dark spots. It carries

its shell in a flattened position rather than upright. The commonest habitat is flood plains. Distributed throughout Indiana. It was twice named by Say, once as *Helix lineatas*.

Genus PUNCTUM Morse, 1864

Very small, umbilicate, with vertical riblets crossed by fine striae. One species only in Indiana.

Punctum pygmaeum (Draparnaud).—This is a circumboreal snail which was observed by Daniels in Jackson, Crawford, Floyd and Kosciusko counties, and it is very likely of statewide occurrence. It lives in shaded areas under sticks and logs.

Family PUPILLIDAE

Of several genera, the shells of which are alike in being minute, higher than wide and with a continuous peristome which is more or less thickened. The eye-stalks are swollen at the end, the tentacles very short. The body is so short that the shell projects beyond the posterior end. The following guide, with modifications, has been adapted from F. C. Baker (1939):

- | | |
|---|--------------------|
| 1. Aperture with 1 or more denticulations or plaits | 2 |
| Aperture without denticulations | 3 |
| 2. Peristome with a constriction or indentation near the middle..... | <i>Vertigo</i> |
| Peristome lacking such a constriction | <i>Gastrocopta</i> |
| 3. Aperture with lip thickened, or reflected, lacking dentations | <i>Pupoides</i> |
| Aperture with reflected lip, 0 to 2 dentations | <i>Pupilla</i> |
| Cylindrical, aperture without reflected lip and without dentations..... | <i>Columella</i> |

Genus GASTROCOPTA Wollaston, 1878

Call includes species of this genus under *Pupilla* and *Leucochila*. It is identical with *Bifidaria*, the generic name that Daniels used. The shells have a waxy appearance and seem never to exceed four or five millimeters in height. The aperture is closed more or less with denticles. The species of the middle western area apparently all winter as eggs and in spring develop rapidly toward maturity. The mollusks are to be found under wood and leaves in damp forests, in flood plain debris and on damp limestone. Every board of a farmyard may shelter one or two specimens. *G. rupicola* (Say) of Moore and Butler's list is an error.

Gastrocopta armifera (Say).—Of about seven whorls, the largest or broadest being in advance of the body whorl. The aperture has a strong pallial tooth, and three to five smaller ones. Varying from the typical form are subspecies *similis*, *affinis* and *abbreviata*, all defined by Sterki. Any one of the several phases should be found in every county of the state.

G. contracta (Say).—Much smaller than *G. armifera*, the aperture nearly choked with denticles, four in number. It lives under boards, chips, pieces of bone and in clumps of grass. It has been seen among clinkers of a railway embankment, seemingly not only a very dry situation but also hot. Common throughout Indiana. A southern form, *G. contracta climeana* Vanatta was reported from southern Illinois by F. C. Baker (1939), and may also be in parts of this state which border the Ohio River.

G. holzingeri (Sterki).—Elongate as compared with *G. contracta*, whorls five, the outer lip broadly reflected. There are two strong denticles and three or four smaller ones. Reported by Daniels as from Dunreith, Henry County, and probably occurring in small numbers throughout the northern half of the state.

G. pentodon (Say).—Cylindrical, less than two millimeters in height, the aperture with seven to nine denticles. Occurs throughout Indiana, most commonly in uplands.

G. tappaniana (C. B. Adams).—Usually larger than *G. pentodon*, otherwise much like it. It lives in damp lowlands, close to streams, marshes and ponds. Of general distribution.

G. corticaria (Say).—Cylindrical, under three millimeters in height, the aperture with a parietal and a columellar tooth. Colonies small, but doubtless in all parts of Indiana under stones and in debris of sticks, and damp moss and grass.

G. procera (Gould).—Reddish brown, elongate or cylindrical, aperture nearly square and with five denticles. Reported by Daniels as in Fayette, Posey and Lawrence counties. In Ohio, the north-south drainage divide is apparently a barrier against northward extension of this species, and the same thing may be true in Indiana.

Genus VERTIGO Müller, 1774

Shell minute, globose to cylindrical, the outer lip in-folded, aperture guarded with denticles. The animal has eye-stalks, but not tentacles.

Vertigo morsei Sterki.—Subcylindrical, about three millimeters in height, the aperture nearly closed by seven or eight denticles. The species was found by Daniels in northern counties, and there is a further record of occurrence in Rush County.

V. ovata Say.—Obese, whorls five, the aperture with three large denticles and four to five smaller ones. Observed by Call in Dearborn and Marion counties, and by Daniels in those near the Michigan state border.

V. ventricosa (Say).—Differing from *V. ovata* in being smaller and of four whorls. The aperture has five denticles, none very conspicuous. A larger form, *V. ventricosa elatior* (Sterki) was found by Daniels, together with the typical mollusk, in the vicinity of James Lake, Steuben County, and in the loess of Posey County by A. A. Hinkley.

V. tridentata Wolf.—Ventricose and of five whorls. The aperture has three denticles, that are equidistant, rather stout. The species has been seen in Dearborn, Hendricks and Henry counties.

V. milium (Gould).—Small even for a genus and family of small mollusks, seldom reaching two millimeters in height. The aperture is nearly closed by denticles. The shell occurs throughout Indiana.

V. bollesiana (Morre).—Less than two millimeters in height, somewhat ventricose and having five denticles. The species was listed by E. Pleas as from Henry County.

V. gouldii (Binney).—"Light chestnut, cylindrical-ovate, . . . ventricose . . . with five prominent white teeth" (Pilsbry). Reported by Pleas as occurring in Henry County and by Daniels as in Fayette and La Porte counties.

V. modesta (Say).—Rather large for the genus, cylindrical and having four white denticles. It has not been found living in Indiana, but is among the Mollusca discovered in the loess of Posey County by A. A. Hinkley.

Genus PUPOIDES Pfeiffer, 1854

Elongate-conic, tapering, of six whorls, red or brown. The peristome is white and reflected. There is a slight umbilication. Only one species occurs in Indiana.

Pupoides marginatus (Say).—The aperture lacks denticles; the peristome broadly reflected, whorls six. Its habitat is under sticks, logs and fallen leaves near bodies of water, and on damp limestone bluffs. Distribution is throughout Indiana.

Genus PUPILLA Leach, 1831

Shell minute, reddish-brown, translucent in fresh specimens; body whorl slightly smaller than the preceding whorl, aperture nearly round. There are 0 to 2 low toothlike projections just within the aperture.

Pupilla muscorum (Linnaeus).—This is a circumboreal species which occurs discontinuously in the middle west of America. It has been found under logs, boards, strips of tar paper, and at least once on the stones of an abandoned field well. Specimens from Indiana have not been reported, but since the species has been observed in Ohio and Michigan it will doubtless some day be found in this state.

Genus COLUMELLA Westerlund, 1878

Spire obtuse, whorls five and below the nucleus of about the same size; aperture nearly round, without denticles; peristome narrow and continuous.

Columella edentula (Draparnaud).—Seen in small numbers under leaves, the trash of flood plains and wood at the edges of forests. It was recorded by Daniels under the genus *Sphyradium* as from Steuben and Kosciusko counties. Another known locality is Corydon, Harrison County.

Family ARIONIDAE

An Old World group of slugs having a vestigial internal shell usually consisting only of calcareous granules which, however, are sometimes hardened into an amorphous mass. Body long when extended, variously pigmented. The mantle is short and entirely forward of the center; eye-stalks long, tentacles scarcely developed.

Genus ARION Ferussac, 1819

Occasional species of the genus are observed in the United States, all of them probably coming as importations with plants. The colonies although sometimes large do not appear to be permanent. These slugs have been described in England as "voracious, especially in early spring, when they eat ravenously, devouring almost any animal or vegetable substances, fresh or decaying, that they meet with." (J. W. Taylor, 1907.)

Arion circumscriptus Johnston.—From twenty-five to thirty-six millimeters in length, principally characterized by dark, sometimes broken, lines of color on a paler background. The species was observed by Mr. Glenn R. Webb in Indianapolis and the finding reported in *Nautilus* 54, 1940, p. 69.

Family LIMACIDAE

A group of slugs having small, thin, non-spiral internal shells. A short mantle is at about the center of the body when this is extended. Near its posterior margin is a breathing pore.

Genus LIMAX Linnaeus, 1758

Large, grayish, grayish-black or mottled. The internal shell is longer than broad. Introduced from Europe.

Limax flavus Linnaeus.—The species reaches a length of about four inches. Color varies from light to dark. Extended, the slug is narrow, its eye-stalks slender and tapering. Most commonly seen in greenhouses. Colonies out of doors are apparently killed by frosts. The slug was reported by Call as occurring at Lawrenceburg; at New Albany by Daniels. Doubtless, where it finds protection from cold weather, it has established itself in other Indiana communities.

Genus DEROCERAS Rafinesque, 1820

Seldom reaching fifty millimeters in length. The mantle is narrow, lobe-like and has a breathing pore near the margin of one side. The generic term used by Call was *Limax*; the one by Daniels, *Agriolimax*.

Deroceras gracile Rafinesque.—This is the *Agriolimax campestris* Binney of early lists. Averaging about twenty-five millimeters in length, grayish-black to black; very slimy. From habitats in woods and at the edges of marshes, this slug has extended its range to gardens, factory yards, dump heaps and the depressions beside cement sidewalks. Distribution is throughout Indiana.

D. agreste (Linnaeus).—Larger than the foregoing, gray, yellow-gray to nearly black. The mantle is narrow and occupies the fore part of the animal. This is an Old World slug which has become acclimated in North America from Moose Factory on James Bay, Ontario, southward. It is sometimes in great numbers among timbers of abandoned factories and dwellings. It does damage to young vegetation. Daniels observed it at La Porte.

Family PHILOMYCIDAE

Slugs in which the mantle covers the greater part of the body. There is a small internal shell.

Genus PHILOMYCUS Rafinesque, 1820

The largest of middle American slugs. The edge of the body shows below the mantle, which is white mottled with dark spots. There are rows of low, irregular tubercles on the mantle.

Philomycus carolinianus (Bosc).—This slug inhabits deep woods, living under started bark and at the edges of logs. In wet seasons, it may sometimes be seen eight or ten feet up the trunks of trees. It is seldom in numbers exceeding five or six, but in suitable situations throughout Indiana. Call placed the species under the genus *Tebennophorus*. He considered its coloration protective.

Genus PALLIFERA Morse, 1864

About twenty-five millimeters long, the mantle covering the slug for about three-quarters of its length.

Pallifera dorsalis (Binney).—Black or nearly black, the mantle with obscure streaks or furrows; eye peduncles short, club-shaped. The mollusk lives in damp woods and is commonly restricted to such habitats, although Call speaks of it as occurring in driftwood lodged on the banks of rivers. Probably in all Indiana areas.

Family STROBILOPSIDAE

Shells very small, pyramidal, with strong axial striae and a series of lamellae on the base and the parietal wall. Animal so small as to seem out of proportion to the shell, anterior parts black, posterior nearly white; tentacles short and on the inner base of the eye peduncles, which are thick and blunt.

Genus *Strobilops* Pilsbry, 1895

The species differ from one another in shape of shells and number and position of the apertural lamellae. The usual habitat is low, wet ground under rotting wood, very often within a few feet of standing water; on one occasion, numbers were taken from beneath a mildewed newspaper.

Strobilops labyrinthica (Say).—Under 3 mm. in diameter, recognizable by the smooth ends of two parietal lamellae which project beyond the aperture. Lips reflected, umbilicus open. Common apparently only in the southern parts of Indiana. Certain modifications are recognized as forms or varieties, rather than as subspecies. They occur in colonies of *S. labyrinthica* typical.

S. affinis Pilsbry.—Larger than the foregoing, the striae coarser, one lamella alone showing in the aperture. As the species has been seen in Dearborn and Kosciusko counties, it is probably to be found throughout the state.

S. aenea Pilsbry.—Flatter than the other two species, angled at the periphery and showing two low lamellae in the aperture. An occupant of wooded

uplands. It has been seen in Illinois and Michigan, and doubtless occurs also in Indiana.

Family VALLONIIDAE

Shells under 3 mm. in diameter, waxy-white, translucent, umbilicate; the outer lip reflected in most middle western species, umbilicus open. The animal is pale yellow, gray or white, unicolored. Eyes at the end of stalks, which are bluntly rounded; tentacles short and placed below and apart from the eye peduncles. The shell is borne over the posterior end of the body.

Genus VALLONIA Risso, 1826

Differences in the species are in shape and sculpture of the shell. Two of the four species have proved to be among the most adaptive of American land mollusks since they extended their habitats from the margins of woods and flood plains to gardens, stables, cellars and the edges of concrete sidewalks. Apparently, the genus has seasons of extreme fecundity, occurring then in thousands.

Vallonia pulchella (Müller).—Surface of shell smooth, shining, the whorls regularly developed. It can be found in every square mile of Indiana in all likelihood.

V. excentrica Sterki.—Shape elliptical or ovate rather than round. This is particularly noticeable in the umbilicus. Somewhat smaller than *V. pulchella*. Known in Indiana from Dearborn, Starke, St. Joseph and La Porte counties, and doubtless could be found in every other section of the state.

V. costata (Müller).—Distinguished from *V. pulchella* by closely-set epidermal ribs. The habitats the two species occupy are of the same kind and as they are sometimes together the question has been raised as to whether they are specifically identical. Reported by Daniels as from Marshall County. His collection contains specimens also from Fayette and La Porte counties.

V. parvuli Sterki.—Having the epidermal ribs of *V. costata*, but in shape and size flatter and smaller. Usually in large colonies when observed in the middle west. It has been collected in Ohio, Michigan and Illinois and so probably inhabits Indiana although so far it has been overlooked in the state.

Family COCHLICOPIDAE

Elongate, smooth, shining and of a golden color. The animal is blackish, the foot somewhat paler than the upper parts. The eye stalks are about one-third the length of the outstretched snail; the tentacles very small. A boreal mollusk going quite around the world in upper latitudes and extending into North Africa.

Genus COCHLICOPA Ferrusac, 1821

Length about six millimeters, imperforate, the apex broadly rounded, the aperture ovate, the outer lip slightly reflected.

Cochlicopa lubrica (Müller).—Shell and animal as described above. It lives under logs and fallen leaves, sometimes in grass and beneath stones. It

may occasionally be found in damp cellars. Like *Vallonia*, it has periods in which it multiplies manyfold and migrates from hiding places into areas quite open, such as paved driveways and concrete sidewalks. It occurs throughout Indiana.

Family SUCCINEIDAE

Shells very thin, whitish to reddish, usually transparent. The early whorls are small and the body whorl greatly enlarged, the outer lip simple. The animal is of a golden color to nearly black, is often larger than its shell. Eye peduncles short, the tentacles hardly more than feeble nodulous projections.

Genus SUCCINEA Draparnaud, 1801

The few species of this genus which occur in the middle west are yet of widespread distribution and may be found with little searching. Although the shells are delicate and friable, they have lasted well in a subfossil stage and are fairly abundant in Pleistocene deposits that are made up largely of terrestrial mollusks. The following is a guide to Indiana forms:

1. Spire prominent, whorls loosely coiled; length of aperture less than half the shell length; usually coated with dirt.....*avara*
2. Spire small, whorls tightly coiled; length of aperture more than half the entire shell length; shell usually shining.
 - a. Body whorl large, expanded, shouldered, aperture broadly ovate.....*ovalis*
 - aa. Body whorl compressed; not distinctly shouldered, aperture elongate.....*retusa*

Succinea avara Say.—Of three whorls, the first two well developed, the body whorl large but not conspicuously expanded. In young shells, the epidermis has numerous short hair-like projections to which dirt becomes adhered and acts seemingly as a protection. The species is fairly common in woods, at the edges of swamps and under sticks and boards in damp gardens. Daniels found it in Kosciusko, La Porte and Whitney counties, and Call considered it as occurring all over the state, which is doubtless correct. Subspecies have been recognized because of differences in sizes of individuals. The distinctions are of doubtful value. Such a form which Say named *S. vermata* was described as inhabiting "margins of ponds near New Harmony."

S. retusa Lea.—Of very short spire, a large patulate body whorl. It is seldom to be seen more than a few feet away from bodies of water and is sometimes observed afloat, the body upward. A common habitat is the stems of cat-tails. It is dark-colored in spring, altering to a bright yellow color as warm weather advances. Common in northern Indiana, and probably it is distributed well over the state. Varieties *decampii* Tryon, *peoriensis* Wolf and *magister* Pilsbry differ from the typical form mainly in size. *S. calumetensis* Calkins of the Daniels compilation is a synonym.

S. ovalis Say.—Large for the genus, yellow to red, green or gray; the body whorl more rounded than in *S. retusa*. It inhabits damp woods and it has been seen eight or ten feet up the trunks of trees. It was reported by Daniels first from Fulton County and later from La Porte, Starke, Marshall, Delaware and Posey counties.

S. indiana Pilsbry.—Whorls three and a half, wide in proportion to height, the body whorl regularly rounded. The species is related to southern forms of the genus. The type lot was found by L. E. Daniels at New Harmony, and that remains the only known locality. Inasmuch as the shells have not been seen since in any other place and may have been an evanescent colony, the species has not been included in the above key.

Family ELLIOBIIDAE

The family consists for the most part of mollusks which live either in salt or brackish water. One genus in the United States has made such anatomical and physiological adaptations as to become classified with terrestrial invertebrates.

Genus CARYCHIUM Müller, 1774

Shells white, translucent to transparent, very small. The animal is colorless, the rostrum broad and marked off from the short body by a shallow suture. The eyes are at the bases of short, blunt tentacles.

Carychium exiguum (Say).—While Say placed the species with the Pupillidae, he ventured the opinion that it actually belonged to *Carychium*. The shell is waxy-white, shining, of less than two millimeters in length and of fewer than five whorls. The outer lip is reflected. On the columellar fold are two projections which are terminations of lamellae which circle the shaft of the axis. This minute snail is to be found under logs in damp places which, in spring, are partially under water. Distribution is throughout Indiana.

C. exile H. C. Lea.—More slender than the foregoing species, the aperture smaller, and the surface striate. It was observed by Daniels only in the northern counties, but as it has been found in drift of the Ohio River at Vevay, Switzerland County, it probably occurs throughout Indiana. A form with greatly thickened aperture is known as subspecies *canadensis* Clapp. It has been found in southern Michigan and very likely also occurs in north Indiana.

Family HELICINIDAE

Distinguished particularly by the possession of a chitinous operculum, in this regard resembling no other terrestrial mollusk of Indiana but rather the Viviparidae and Amnicolidae.

Genus HENDERSONIA A. J. Wagner, 1905

Shell small, orbicular, imperforate, the outer lip reflected, operculum horny. Only one species occurs in Indiana.

Hendersonia occulta (Say).—Whorls five, the early ones carinate or keeled, the mature one rounded. The habitat is forest debris, shaded limestone bluffs and crevices of old stone walls. Say's specimens, which were dead and bleached, were "in the ragged and abrupt 'bluff' half a mile below New Harmony." The species is not mentioned by Call, but Daniels found specimens in marl beds of Posey County, and would seem to have considered the species extinct in Indiana.

Family LYMNAEIDAE

For the most part, species of the family which occur in Indiana have thin exo-skeletons, yet relatively this character may vary decidedly between occupants, say, of a woods pool or a horse trough and those living in the shallows of Lake Michigan. Also for the most part, the shells are elongate, the spires high, but there are a few species of short, tightly-coiled spires and large body whorls. Sculpture aside from the axial growth lines consists of revolving thread-like markings more or less microscopic and sometimes undulate. The columella may be thin or thick, raised above the umbilical chink or folded upon it tightly. Varices in the shell substance register pauses in growth, and are not of specific significance. The jaw of the animal shows modifications according to age. The radula is ribbon-like, the lateral teeth multicuspid. F. C. Baker has divided the family into several genera, but as this has not been generally accepted the mollusks are here kept within the one genus.

The following is a much simplified guide to Indiana species of Lymnaea according to shell characters:

1. Large, elongate, spire slender and acute, body whorl flaring *stagnalis appressa*
2. Large, thick, elongate, spire obtuse; dark-colored *megasoma*
3. Of medium size (length 25 mm.), elongate, usually reddish-brown
 - a. Spire obtuse, body whorl not flaring.
 - b. Whorls not shouldered; longer, averaging 25 mm.
 - c. Shell malleated, 2 to 3 times as high as wide; columella moderately twisted *palustris*
 - cc. Shell smooth, about 4 times as high as wide; columella strongly twisted *reflexa*
 - bb. Whorls distinctly shouldered; shorter, averaging 18 mm. *kirtlandia*
 - aa. Spire obtuse, body whorl flaring *danielisi*
 - aaa. Spire acute, body whorl not flaring *exilis*
4. Small, very thin and attenuate, aperture narrow, produced *haldemani*
5. Of medium size (10 to 12 mm.), rather thick, usually white to light brown.
 - a. Elongate, spire obtuse *calascopium*
 - aa. Globose, spire short and tightly coiled *woodruffi*
6. Aperture very large, spire short, tightly coiled.
 - a. Large, roundly ovate, aperture horizontally flaring *auricularia*
 - aa. Small, *Succinea*-like, aperture vertically flaring *columella*
7. Small, spire obtuse, epidermis raised into undulate lines to form a characteristic cross-hatch pattern.
 - a. Adults usually 8 mm. in length *caperata*
 - aa. Adults usually 16 mm. in length *umbilicata*
8. Very small, thin, whorls rounded to shouldered, aperture ovate to nearly round, columella flattened to raised.
 - a. About 8 mm. or less in length, spire longer than aperture
 - b. Aperture narrowly elliptical *parva*
 - bb. Aperture broadly elliptical, almost round *dalli*
 - aa. Usually more than 8 mm. in length, spire as long as aperture.
 - b. Smaller (averaging 9 mm.), aperture ovate, not extended at base *humilis modicella*
 - bb. Larger (averaging 12 mm.), aperture elongate-ovate, extended at base *obrusa*

Genus LYMNAEA Lamarck, 1799

Lymnaea stagnalis appressa (Say).—The specimens from which the description was drawn came from Lake Superior, but the subspecies is of wide

distribution in northern latitudes of the United States. It is the largest of American lymnaeids, and is easily recognizable by its elongate spire and very much enlarged body whorl. It is a mollusk of stagnant waters and where the locality has been undisturbed it is usually in large numbers. It appears to be intolerant to domestic sewage. Call did not observe the shell in Indiana. Daniels found it in small lakes and in slow-moving streams of the northern part of the state, and in Lake Michigan, this last probably being drift material.

L. auricularia (Linnaeus).—Spire very short, the last whorl greatly enlarged, the adult shell having a globose appearance. This is an Old World mollusk that rather rapidly is becoming established in North America. Since some of the earlier-known colonies of the Great Lakes region are disappearing, it is surmised that after a few generations in the newer situations factors are arising which are acting as a check on reproduction. The species has not been reported from Indiana, but possibly could be found in quiet waters bordering on Lake Michigan.

L. columella Say.—Distinctive because of a short spire and a wide, flaring, Succinea-like body whorl. It occurs in both standing and running waters, and has been taken in small streams that are turbid with farm wastes. It was not observed in Indiana by Call, but was found by Daniels in northern counties. Inasmuch as the mollusk occurs as far south as Florida, it should be in almost every Indiana county. A subspecies, *chalybea* (Gould), inhabits Kosciusko and Lake counties. *L. columella casta* (Lea) is rather narrow, more elongate than the typical form, and is marked with revolving raised lines. Shells of the kind occur in Bass Lake, Starke County, and in the vicinity of La Porte.

L. megasoma Say.—A large, brownish-black shell, usually much malleated, aperture wide and ovate, the interior dark purple or reddish. It reaches a length of nearly fifty millimeters. The body is dark, the fore part marked with spots of yellow. The mollusk lives in shallows of marshes, lakes and streams, sometimes in numbers. This is a boreal species which has an outlying colony in northern Ohio and it seems likely that it may also occur in lakes or swamps of Indiana north of the Wabash River valley.

L. haldemani Deshayes, Binney.—At the opposite extreme of *megasona* in shell, texture and shape, being small, attenuate and translucent. It is of irregular distribution from Illinois to Vermont and parts of Canada and is, so far, unknown in Indiana, but may be in the lake region of the state among growths of *Typha*.

L. caperata Say.—Described in the New Harmony Disseminator of Useful Knowledge in 1829 from specimens of Posey County "found on land subject to inundation." Fresh shells are reddish and sculptured with undulate spiral lines of varying conspicuousness. It is an inhabitant of ponds, temporary pools and ditches, and is able to endure long periods of desiccation. It has been seen in great numbers in pools left by rivers after flood. Probably in every county of Indiana.

L. umbilicata C. B. Adams.—Smaller than *L. caperata*, but with much the

same sculpture. As the name indicates, the umbilicus is conspicuous. The species is listed by Daniels as from Liverpool, Lake County.

L. parva Lea.—A very small, shouldered shell of about six whorls which lives in ponds, lakes and brooks. Daniels' collection contains specimens of the species which he found in Wawasee Lake, Kosciusko County, a cypress swamp of Knox County; Starke, Steuben and La Porte counties. A subspecies, *sterkii* Baker, is more stoutly shouldered than the typical form, appearing "like boxes of diminishing size set one upon another" (F. C. Baker, 1911.). Known from Knox and Marshall counties.

L. dalli F. C. Baker.—The smallest of American Lymnaeidae, the length of the largest specimens observed being only four and a half millimeters. The type locality is a marsh on the west side of James Lake, Steuben County. (L. C. Daniels, collector). Reported also from Marshall, Kosciusko and La Porte counties.

L. humilis modicella (Say).—Named by Say from Pennsylvania forms, but the species is of very wide distribution in northern North America and is sometimes to be seen in great numbers on the mud flats of streams, ponds and lakes. The shell is seven to twelve millimeters in length, of a light to dark brown color.

L. humilis rustica (Lea).—Much more elongate than *modicella*. Found by Daniels in Lake James, Steuben County, but may have a much wider range through the state.

L. obrossa Say.—This is the *L. desidiosa* of the Call and Daniels lists. It is one of the small forms of the genus although occasional specimens are seen that acquire a length of twenty millimeters. The body whorl is noticeably flattened. It occupies the same kinds of stations as *L. humilis modicella*. Doubtless, it can be found in any Indiana county.

L. obrossa exigua (Lea).—More elongate than the typical form, and tending to be scalariform. It was found in Little Kankakee River, La Porte County, by Daniels, and in lakes and springs of Steuben and Marshall counties.

L. obrossa decampi (Streng).—This subspecies has a much enlarged body whorl with a correspondingly large aperture, accommodating a broadened foot with strong clinging power. It has been observed on the pilings of boat wharves feeding upon algae. The shell is especially common in Pleistocene deposits. It has been taken in Pleasant Lake, Steuben County, and should be in other parts of the Indiana lake region.

L. palustris (Müller).—This is the elongate, frequently malleated, shell which is common in ponds, ditches, slow-moving streams and shallow parts of lakes. Its feeding on algae on stones can sometimes be seen as a narrow, irregularly-shaped path. Present throughout the state. A subspecies *michiganensis* Walker is mentioned by Daniels as inhabiting lakes in Kosciusko and Lake counties. This is a small depauperate form with a thick deposit of callus just within the outer lip, and in woods pools has long periods of hibernation and aestivation. Its peculiarities are ecological responses.

L. palustris desidiosa (Say).—Credited by Say to New Harmony, Posey County. "Compared with *palustris*, *desidiosa* is smaller, usually more solid and with a more obese body-whorl and a more dilated aperture." (F. C. Baker, 1911.)

L. palustris blatchleyi F. C. Baker.—A mollusk of longer proportionate spire than typical *palustris* and a rounded rather than a flattened body whorl. It is one of several localized races the characters of which might prove, upon experiment, to be reactions purely to ecological conditions. The type locality is Turkey, now Wawasee Lake, Kosciusko County. The first specimens were collected by Daniels. Tippecanoe Lake is mentioned by him as another locality.

L. palustris elodes (Say).—Considered distinct from typical *palustris* by F. C. Baker "in having more loosely coiled whorls and in being narrower and more attenuate, with more flat-sided whorls." It is to be expected in pools that are cut off from main bodies of lakes by low sandbars and in which heavy masses of vegetation have developed. Known from Lake, Kosciusko and La Porte counties.

L. palustris jolietensis (Baker).—A small race, tending to be scalariform. Found in Illinois and Michigan, and so probably occurring in Indiana. The various forms of *palustris* to which subspecific names have been given on the strength of peculiarities of shell may all be reflexes of environment and may be found, upon test, to alter as their living conditions are changed.

L. reflexa Say.—Resembling *L. palustris*, but the mollusk has a peculiarly distorted aperture, a very large body whorl and a spire of greater length than the aperture. Say's specimens were from Lake Superior, or its region, which is about as far as the species extends to the north. Daniels speaks of the mollusk as common in northern Indiana, but it probably occurs also in counties along the Ohio River. This is one of the freshwater mollusks which are highly tolerant to polluted waters; it has been observed in fairly large colonies at the discharges of sewers.

L. exilis Lea.—The spire is elongate, spear-like, the whorls flattened and the aperture small and ovate. The attenuate shape is correlated with soft parts suggesting depauperization, and as the species is an inhabitant of marshy localities the waters of which frequently disappear in mid-summer the tenuousness of the shell as well as the failure of the animal to acquire the development of *palustris* may be another instance of ecological response. *Exilis* was found several years ago in Lake County and recently in a small pond of Elkhart County.

L. kirklandiana Lea.—A thin, turretted shell, often translucent, the species living in small bodies of water that are pools left by streams after flood. Daniels reported it from Roby, Lake County, and it has been seen also in Hendricks and Cass counties.

L. danielsi Baker.—Found in Lake Maxinkuckee, Marshall County, by Daniels, and believed by him to be an inhabitant of the deeper waters. It bears

some resemblance to *L. stagnalis appressa*, but is of the group of *L. palustris*. It is remarkable for the large, flaring aperture. Besides Lake Maxinkuckee, it is known from Wawasee Lake, Kosciusko County, and Pleasant Lake, Steuben County.

L. catascopium Say.—Resembling *L. palustris*, but is more obtuse of spire, usually much thicker and of fewer whorls. The species is particularly common in the Great Lakes, and is known to be singularly resistant to pollution. It is reported from Calumet Lake, Lake County, by F. C. Baker, and it should be in other bodies of shallow water near Lake Michigan.

L. woodruffi F. C. Baker.—A small, thick shell of short spire, and thought to be an occupant of deep water in the southern loop of Lake Michigan. No living examples have been seen. It is thrown in great numbers on the beaches of Lake and La Porte counties during storms.

Family PLANORBIDAE

The spires of the shells are very slightly raised, upon the same plane with succeeding whorls or engulfed by them. The shells range from minute to more than an inch in diameter, from smooth to rough in texture. Tentacles of the animal are long and slender, noticeably active. The pattern of the radula differs from genus to genus. Four genera occur in Indiana.

The genera of Planorbidae which occur in Indiana can be distinguished from one another by shell features as follows:

1. Large, ultra-sinistral, spire sunken, umbilicus deep.....*Helisoma*
2. Much smaller than *Helisoma*, ultra-dextral, flattened, periphery subangulate to carinate.....*Cyraulius*
3. Small, ultra-dextral, periphery rounded; aperture with tooth-like lamellae.....*Planorbula*
4. Very small, ultra-dextral, depressed, deeply umbilicate, carinate.....*Menetus*

Genus HELISOMA Swainson, 1840

Under this name are grouped the largest members of the family. These are sufficiently distinct from one another to be placed in three subgenera. Their habitats, for the most part, are shallow waters of ponds, woods and fields pools, swamps, marshes and slow-moving streams.

Helisoma trivolvis (Say).—The mollusk was described by Say while he was a resident of Philadelphia from specimens that were brought him from the middle west although the species was far from rare in his own region. It is commonly an occupant of stagnant water and yet establishes colonies in brooks and creeks. Call speaks of the species as exceedingly abundant among reeds of the smaller lakes of Indiana. It is hardly likely to be absent from any rural township of the state. Probably as eggs and transported in mud on the legs of birds, it gets occasionally in tanks, reservoirs and watering troughs.

H. pseudotrivolvis F. C. Baker.—A shell of small height as compared with diameter, and commonly identified as *trivolvis*. Baker (1928) mentions that he has seen specimens from Indiana.

H. antrosum (Conrad).—The name has recently been displaced by *H. anceps* (Menke) on the basis of an illustration unaccompanied with descrip-

tion and the identity of which is a matter of individual inclination. It is in the older Indiana lists as *Planorbis bicarinatus* Say. It has a low-sunken spire and a deep umbilicus, a rather large aperture. Probably in every part of Indiana. A number of subspecies which are either localized races or ecological modifications have been recognized, most of them occurring in the upper Great Lakes regions. Some of these may occur in the lakes area of Indiana.

H. campanulatum (Say).—A tightly-coiled shell with a bell-like expansion of the aperture. Call speaks of it as "over nearly all the state," but in all likelihood it is mostly restricted to the lakes area. It is apparently intolerant to domestic sewage and in course of disappearance. *H. campanulatum ferrissi* (F. C. Baker) is recorded as a Pleistocene mollusk in Illinois and may possibly be in similar deposits in Indiana.

Genus *GYRAULUS* Agassiz, 1837

Shell dextral, the spire seldom rising above the plane of succeeding whorls; periphery angled or slightly rounded; epidermis bearing hair-like projections in spiral lines in two species.

Gyraulus hirsutus (Gould).—The hirsute character providing the specific name is pronounced in young and adolescent snails and may be absent in old and worn specimens. The species is the *Planorbis albus* of the Lake Maxinkuckee list. It inhabits stagnant pools, quiet lakes and streams, having large growths or patches of vegetation. Observed in lakes of La Porte, Marshall, Starke, Steuben and Lake counties; Grassy Creek, Kosciusko County, and Calumet River, Lake County.

G. deflectus (Say).—Much like the preceding species in shape, but less hirsute and having a sharply angled or carinate periphery; the base a little concave. Ecology identical with that of *G. hirsutus*. Call says that he found the shell only among the lily-pads of a pond at Lawrenceburg, Dearborn County. It was taken by Daniels in Lake James, Steuben County, and probably occurs throughout the state.

G. parvus (Say).—A very small and common mollusk of ponds, lakes and slow-moving streams, and often in numbers on the under sides of lily-pads. It is the only *Gyraulus* mentioned by Pleas and was overlooked by Moore and Butler. Doubtless in every Indiana county.

G. circumstriatus (Tryon).—Differentiated from *parvus* by the possession of spiral lines, but it has been found to occupy the same ponds and pools with it, with gradations from conspicuous sculpture to none at all. Specimens from Lake James, Steuben County; Lake Maxinkuckee, Marshall County, and Webster Lake, Kosciusko County, have been seen.

G. circumstriatus walkeri (Vanatta).—Of fewer whorls than the typical form, the whorls more rounded. A fold of callus lies just within the aperture. It should be in Indiana as it occurs in the neighboring states.

G. altissimus (F. C. Baker).—Cited from Indiana by Baker. A Pleistocene shell and believed by Baker to be evolutionarily a predecessor of *parvus*. Not known in the living state.

G. umbilicatellus (Cockerell).—The largest species of the genus. The whorls are slightly angled and they bear revolving raised lines. Known in Indiana from Tippecanoe Lake, Kosciusko County.

G. cristus (Linnaeus).—A very small discoid shell, flattened on top and having distinct projecting ribs. It was thought for a long time to be an introduced mollusk, but it has been found in various places in the United States where the introduction of Old World forms would be unlikely. It lives on stems of aquatic plants in shallow waters. Two forms recognized in Europe as distinct have been seen in America also, *imbricatus* (Müller) and *cristatus* (Draparnaud). The latter, in association with *cristus*, was collected by Daniels in a marsh on the west side of Lake James, Steuben County.

Genus PLANORBULA Haldeman, 1842

Shell multispiral, the later whorls rising above the earlier ones. Aperture a little expanded, and protected with six lamellae, two on the parietal wall and four on the outer wall.

Planorbula armigera (Say).—Not observed by Call, but reported by Pleas as occurring in Henry County. Blatchley and Daniels remarked its presence in thousands in Carr's Slough, White County. The Daniels collection contains material from Lake, La Porte, Steuben, Marshall and Kosciusko counties. The mollusk lives in stagnant pools, in marshes and swamps, and is everywhere remarkably uniform of shape and size. It undergoes in places periods of dormant existence.

P. crassilabris (Walker).—The author described this as smaller than *armigera*, more compactly coiled and higher in proportion to diameter. The lamellae are also slightly different. There is a thick development of callus just within the outer lip. The habitat is much the same as that of *armigera*, but apparently the pools it occupies are of short duration; the periods of aestivation and hibernation which the mollusks in them endure, very long.

Genus MENETUS H. and A. Adams, 1855

A small, very much flattened, sharply keeled group of mollusks, usually dark red or brown, thin and translucent. Radula similar to that of *Gyraulus*.

Menetus exacuus (Say).—Described from specimens found in Lake Champlain, a rare habitat since commonly the species lives in swamps, pools and other such standing waters. On grounds of etymology, Call used the corrected spelling *exacutus*, but as Say on two different occasions employed *exacuus* it is held to be the proper nomenclatorial term. Found by Call in Dearborn County and by Daniels in several northern counties. It may be assumed to occur throughout the state.

M. rubellus (Sterki).—Smaller than *M. exacuus*, the apex very much sunken. The Walker collection contains a single lot that is labelled "Indiana." As it is fairly common in southwestern Michigan, it should be also in Lake and La Porte counties, Indiana.

M. dilatatus buchanensis (Lea).—Deeply umbilicate, the periphery carin-

ate, the aperture "trumpet-shaped." It has much the same kind of habitat as *exacuous*. Drift specimens were found by Daniels on the shores of Lake Michigan, Michigan City, La Porte County. These were in all likelihood washed into the lake from some small inland pond or pool. The typical form was found in Blue Lake, Whitley County.

Family PHYSIDAE

Shell sinistral, smooth to rough, with revolving, sometimes wavy, lines which usually are quite plain in young mollusks and frequently worn away in mature individuals. Whorls may be tightly or loosely coiled, the aperture elongate-ovate or nearly round. The foot of the animal is rather narrow, the posterior end pointed. Mantle spotted. The marginal denticles of the radula have broad folds on which are conspicuous rake-like processes. Two genera of the family inhabit Indiana.

Genus *PHYSA* Draparnaud, 1801

The principal distinction of this genus from *Aplexa* is that the mantle edge has digitations or lobes which are closely appressed to the shell when the animal is extended. These vary in size and number within any one of the species.

Physa heterostrophia (Say).—The species was placed under *Lymnaea* to begin with, and shortly shifted to *Physa*. The whorls are four, moderately coiled; the apex obtuse. Rest periods are registered as black or purplish axial markings. Call has thrown most of the Indiana forms of the genus under this name, giving it a range throughout the state. Although he has not been followed in this course his position in the matter has not been refuted. The common habitat is still or stagnant shallows of ponds, lakes and streams.

P. gyrina Say.—Described from material collected in western Iowa, but the species is the most common member of the genus in the region of which Indiana is a part. The apex is acute, the whorls loosely coiled, the aperture so produced that the central part of the body whorl appears flattened. Call is mistaken in saying that *gyrina* alone has a fringed mantle. Probably most of the Physidae considered to be *heterostrophia* are this species. Distributed throughout the state. In a ditch in Kosciusko County, many thousands were once observed so closely packed together that their smooth shells reflected the sunlight brightly over a distance of a hundred yards. *P. rhombica* Crandall of Daniels' list, cypress swamps of Knox County, is probably *P. gyrina*.

P. gyrina hildrethiana (Lea).—Differing from the typical forms in having a decidedly elongated body whorls. Not observed by Call or Daniels among Indiana mollusks, but known to occur in Henry, Knox, Kosciusko, Marshall, Bartholomew and White counties.

P. gyrina elliptica (Lea).—Smaller than the typical form, more tightly coiled; little variation among individuals making up a colony. Apparently confined to lake shallows, ponds and slow-moving streams. It has about the same distribution as *P. gyrina*.

P. sayii Tappan.—Spire short, whorls tightly coiled, the body whorl large and rounded. An occupant of lakes, and sometimes to be found there on algae-covered boulders of wave-beaten shores; occasionally in streams. Common in northern Indiana.

P. ancillaria Say.—Typical forms of this species have very short spires. The whorls are broadly shouldered, sutures very shallow. While credited to Indiana by Call and Daniels, it is probable that the shells they so recognized come more properly under *P. sayii*.

P. integra Haldeman.—The specimens received by Haldeman were from Mrs. Say, and their locality was given as Indiana. The shell is relatively small, loosely coiled, the body whorl rounded. The varices representing periods of arrested growth are white. This is one of the more distinctly characterized species of the genus, and is more often to be found in streams than in quiet waters. It was not observed by Call. Daniels found it in Crawford County and as drift material in Lake Michigan, La Porte County. The size of colonies ordinarily is small, the individual members somewhat solitary of habit. Other known localities are Eagle Creek, near Indianapolis; Deer Creek, near Logansport; White River at Hazleton; Pigeon River, Evansville; Wabash River, Wabash County; St. Joseph River, Allen County, and Lake James, Steuben County. A miniature form is known as *P. integra billingsi* (Heron).

P. walkeri Crandall.—Narrower than *P. integra*, the spire more loosely coiled, the body whorl less rounded. Possibly depauperate. It is an occupant of small streams that become dry in seasons of drought. It was cited by F. C. Baker (1928) as living in Indiana.

P. michiganensis Clench.—This is the most attenuate of all the American Physidae. The whorls are so loosely coiled that the mollusk appears deformed. The species inhabits brooks, its colonies are usually small. Shells so identified were found in Henry, Knox and La Porte counties.

Genus APLEXA Fleming, 1822

Shell narrow, elongate, usually shining yellow. "Animal similar to that of *Physa*, but with the inner edge of the mantle simple, not digitate nor reflected over on the body whorl" (Walker, 1918).

Aplexa hypnorum (Linnaeus).—A common mollusk of brooks, creeks and woods pools, often in large colonies. The snail is able to endure long periods of aestivation and hibernation, and it has been dug from mud of low spots that are known to have water in them for from only six weeks to six months in the year. In Indiana, it is probably most widely distributed in the lake and marshy areas north of the Wabash River. The generic name used by Call was *Bulinus*.

Family ANCYLIDAE

The generic names of this group of small limpet-like gastropods are based upon shell characters and peculiarities of the radulae; the species upon variations in the shape of shell, the position of the apex and the sculpture, if any. Two genera of the seven recognized by Walker (1918) are represented in

Indiana, and a third probably lives in the Ohio River bordering the state. These mollusks are so unobtrusive that Call remarked only one species in Indiana, Pleas one in Henry County. Moore and Butler came upon none in Franklin County. In all likelihood, however, three or four species could be found in any Indiana county.

This guide to genera of the Ancyliidae has been condensed from Walker (1928):

1. Patelliform, apex turned to the right *Ferrissia*
 a. Apex radially striate subgenus *Ferrissia* s.s.
 aa. Apex smooth subgenus *Laevapex*
2. Patelliform, elevated, apex tinged with pink *Rhodacmaea*
3. Patelliform, apex smooth; a septum in posterior end of the aperture..... *Gundlachia*

Genus FERRISSIA Walker, 1903

Small, thin and delicate, the apex relatively high, usually placed to the right. Sculpture may consist only of fine growth lines, of radial lines or punctation. The animal is sinistral, made fast to the shell by a continuous musculature at the edge of the mantle; the foot relatively large, tentacles short, blunt and with eyes fixed at their inner base. The snails inhabit strams both slow-moving and fast, lakes, swamps, ditches and woods pools. By means of water-borne eggs, the mollusks get into watering troughs and artificial reservoirs. Members of the genus appear to be able to endure a high degree of pollution inasmuch as they have been seen on rocks of streams wherein every other form of mollusca has been destroyed by domestic sewage.

Ferrissia bartschi Walker.—A small, depressed shell, the apex "prominent, blunt, rounded, situated on the posterior third of the shell." The type locality is the marsh at the south end of Lake Maxinkuckee, Marshall County.

F. novangliae (Walker).—"This little species is easily distinguished by its narrow, elongated depressed form, very eccentric apex and the costulate anterior slope." (Walker, 1908.) Described from Massachusetts specimens and found in a reservoir in Illinois. Possibly in Indiana.

F. haldemani (Bourguignat).—Apex striate, relatively high, the longer slope bearing a few coarse radii. Doubtless in Indiana inasmuch as it occurs in Illinois and Michigan.

F. parallela (Haldeman).—The most striking characteristics of the species are its narrow base and the straightness of the lateral margins. It is radially striate. In Lake Maxinkuckee.

F. pumila (Sterki).—Small, thin, shining, oval, the apex radially striate and turned to the right. It is known from the Kankakee River of Illinois and is perhaps in the Indiana part of that stream.

F. rivularis (Say).—Ovate, margins curved, the apex slightly sloping toward the right, radially sculptured. First of the American Ancyliidae to be described, its habitat given by Say as upon "stones in rivulets." Recorded from Lake, Knox and Henry counties.

F. shimekii (Pilsbry).—Apex high, "off the center," radially sculptured, the posterior slope concave. One of the four species of the family that were observed during the faunal survey of Lake Maxinkuckee. Taken also in Bass Lake, Starke County.

F. tarda (Say).—Described in the New Harmony Disseminator of Useful Knowledge, January 15, 1840, as a mollusk of the Wabash River. Apex elevated and striate, yellowish to brown, the shell elongate-ovate. Commonly to be found in the larger streams on the dead shells of Naiades. Known from extreme northern and southern counties of Indiana. It is the only species of the family that is mentioned by Call.

F. walkeri (Pilsbry and Ferriss).—Specimens from La Porte County are somewhat depressed, convex on the posterior slope, concave on the anterior slope, marked with fine radiating lines. Found also in Marshall County.

F. diaphana (Haldeman).—"Distinguished by its circular and flattened form and central inconspicuous apex." (Haldeman.) Taken in the Ohio River at the Falls, and probably occurring in larger streams of interior Indiana.

F. fusca (C. B. Adams).—Depressed, oval, apex smooth and hardly raised above succeeding whorls. The species has been collected in lakes of Marshall and La Porte counties, and in Grassy Creek, Kosciusko County. *F. fusca eugrapha* (Pilsbry), a ribbed form, is known from Millers, Lake County.

K. kirklandi (Walker).—Large, broad, the posterior and anterior margins broadly rounded; apex smooth, blunt to acute, elevated. Known from Marshall, Lake and La Porte counties, and is probably more or less generally distributed through the state.

F. michiganensis Winslow.—Small, elevated, the shape suggestive of a pyramid, apex smooth. This species came originally from a pond in Berrien County, Michigan, which borders upon northwestern Indiana and so the species should be expected to occur in similar situations across the boundary line.

Genus GUNDLACHIA Pfeiffer, 1849

The particular distinction of this genus consists in the possession of a septum which closes off part of the body cavity. The radula, although resembling that of *Ferrissia*, appears to be consistently degenerate. As the mollusk has both septate and non-septate stages, Dall (1904) ventured the opinion that "*Gundlachia* is merely an *Ancylus* which has under favorable circumstances been able to form a calcareous epiphragm and survive the winter, which ordinarily kills the great mass of individuals." The rarity and discontinuous distribution of the genus tends to support the contention, but it has not been accepted by Walker, who more than anyone else has studied the family. One species occurs in Indiana.

Gundlachia meekiana Stimpson.—The septate and non-septate phases are so separated from each other as to give the shell a distorted appearance. The

apex has the striae of some species of *Ferrissia*. It was found by Daniels in Clear Lake and in a pond at Camp Colfax, both localities being in La Porte County; also a marsh of Steuben County.

Genus RHODACMEA Walker, 1917

The shells are larger, thicker and more elevated than the other Ancyliidae so far considered. The radulae have developed striking peculiarities, one of which is a marked expansion of the base of the central tooth.

Rhodacmea elatior (Anthony).—"Apex quite acute and turned toward the right. The apical striae are strong and close together at the apex, but rapidly diminishing in size" (Walker, 1904). Anthony described the color of the shell as rosy. The types were from Green River, Kentucky, which discharges into the Ohio River just about opposite Evansville, Vanderburgh County. Certain remarks of Call on *Ancylus* (now *Ferrissia*) *tardus* suggest that in instances he had specimens of *Rhodacmea* without recognizing them as such.

R. hinkleyi (Walker).—Oval, elevated, conic; "light greenish horn color, radical sculpture confined to the apex." (Walker, 1908.) Occurs in the Ohio River, Pope County, Illinois, and is probably in the stream bordering on Indiana as well as in the lower Wabash River.

Family VIVIPARIDAE

Shells of this family are the largest of any gastropods occurring in waters of middle western America, are commonly smooth in the adult stage or sculptured with revolving striae, imperforate or with a slight umbilical chink. Attached to the foot is a corneous operculum which in two of the genera inhabiting Indiana is wholly concentric, in one provided with a subspiral nucleus. Tentacles of females are symmetrical; one in the male is modified into a short, truncated penis. Respiration is by means of gills occupying the right lobe of the mantle. Radulae of each of the genera distinctive.

The genera occurring in Indiana may be distinguished from one another by shell characters as follows:

1. Large, thin, whorls convex, sometimes slightly flattened; epidermis with or without revolving color bands; aperture almost round, operculum wholly concentric.....*Viviparus*
2. Smaller than *Viviparus*, much higher than wide, often cylindrical; early whorls carinate, keeled or striate, sometimes unsculptured; aperture ovate; nuclear part of operculum spiral, post-embryo growth concentric.....*Lioplax*
3. Heavy, thick, high or low-spined, smooth, usually apple-green; whorls convex, occasionally shouldered or flattened; aperture bluish, ovate, narrowing at the top and in old large-river individuals having a deposit of callus near the suture; operculum concentric.....*Campelema*

Genus VIVIPARUS Montfort, 1810

The shells of members of the genus in Indiana are smooth except for rows of epidermal projections suggesting bristles and which usually disappear in the older mollusks. The umbilicus is either closed or partially open. Operculum entirely concentric. Folds of radula multidentate. As the name indicates, the

young develop within the marsupium and are discharged as partially grown shells. These are of greater diameter than height.

Viviparus contectoides W. G. Binney.—Thin, greenish in fresh specimens, the whorls four and rounded, commonly with four dark revolving, deeply-pigmented bands. In Indiana, the species is found in muddy shallows of lakes and streams. Daniels collected it on beaches of Lake Michigan, Lake County, but it would seem that the shells had been washed in from Calumet River. Call speaks of it as common in the Wabash River from Lafayette to the mouth. After high winds, it is to be seen in numbers in the debris of the shores of Lake Maxinkuckee. Apparently it is absent from the eastern and southeastern parts of the state.

V. intertextus illinoisensis F. C. Baker.—Say's *Paludina intertexta* was described in the New Harmony Disseminator of Useful Knowledge in 1829 as from Louisiana. Whorls very much rounded, the last one broad. Bands if they occur are faint. The subspecies differs from the typical form in having a partially open umbilicus, a northern racial modification. It is known from Indiana as from Lake Maxinkuckee, a cypress swamp in Knox County and the lower Wabash River. There is evidence that obesity in this mollusk increases with size of the streams occupied. A mollusk which Say named *Paludina transversa* is the young of this species.

V. subpurpureus (Say).—The shell is dimorphic, a globose form seemingly confined to large streams such as the Mississippi, Ohio and Wabash rivers, a more conic configuration to small bodies of water. The shell is rather thick, solid. The next to last whorl appears to be larger than the body whorl. Yellow or brown spots are scattered irregularly over a body bluish-white in tint. Distribution is in Knox, Posey, Perry and Vanderburgh counties. The type locality is "Fox River, an arm of the Wabash," which is opposite New Harmony.

V. malleatus (Reeve).—This is a large, brownish shell native to Japan which has been extensively imported as a hardy mollusk suitable for aquaria. By means of embryos and, at times, the partly or fully grown mollusk, the species has established colonies in places from California to Massachusetts. It has appeared in such contrasting situations as the Mississippi River and Lake Erie, and possibly now is living in lakes or streams of Indiana.

V. japonicus (von Martens).—Large, dark, with obscure keels on the body whorl; the aperture rounded and bluish. This is another importation that is likely to make an appearance in Indiana. A flourishing colony of it occupies a park lagoon in Jackson County, Michigan, hardly more than fifty miles from the northern Indiana border.

Genus LIOPLAX Troschel, 1856

Shell conic to cylindrical, thick, the early post-embryo whorls marked with carinae or striae, but not always. The operculum is subspiral to begin with and alters with growth to the usual concentric method of development of the family. These are the outstanding characteristics of the genus, but those of the

shell vary markedly even with the same colony. The animal is large in proportion to shell-size. A tentacle of the male is a sexual organ; upper ends of the marginal teeth are acute, and without denticles.

Lioplax subcarinata occidentalis Pilsbry.—Typical *subcarinata* (Say) was described from Delaware River forms. Western forms have been considered distinct. Material from the Wabash River taken by Van Cleave and Chambers has been determined by Pilsbry as his subspecies *occidentalis*. Aside from its sculpture and operculum, the mollusk is of six whorls, usually pale green and often with broken to entire spiral lines near the suture of the body whorl. The common habitat is the muddy stretches of slow-moving streams in depths of a few inches to four or five feet. Probably all *Lioplax* of the Ohio River and its tributaries are this form.

Genus CAMPELOMA Rafinesque, 1819

Heavy, thick, unsculptured except for rows of slight projections in the epidermis which are of such rarity as to appear to be reversions; whorls smooth, seldom exceeding six. Umbilicus usually covered by the columellar fold, operculum concentric. Central tooth with a single fold, laterals and marginals acute and lacking denticles. As in other genera without sharply-cut characters, this genus has acquired a burden of specific names — differences being established on points seldom verifiable with measurements. No differences in soft parts as among species so-styled have been found. Females run to larger size than do males, as Call demonstrated. Sinistral shells occasionally appear, but for the most part they do not grow beyond the uterine stage. High-spined forms occur in lakes and small streams, the low-spined ones in such rivers as the Ohio and the lower Wabash. The habitat as a rule is in mud where the current or wave-action is slight, although in one place shells were seen in patches of algae on the apron of a dam. The two contrasting forms are considered first in this compilation, followed by others which have been assigned to Indiana.

Campeloma decisum (Say).—No location was given by Say except "various parts of the Union." At different times, illustrations were supplied for his descriptions, one showing a shell of high spire, another of low. The first is the one agreed upon as the true *C. decisum*. It inhabits all sections of Indiana, and is especially common in the lake region north of the Wabash River.

C. ponderosum (Say).—This is a robust, low-spined, large-apertured form which Say reported as living in the Ohio River and some of its tributaries. Specimens coming within the diagnosis have been taken in the Wabash River from Lafayette to Grand Chains. It is known to inhabit the lower parts of the West Fork of White River; the Muscatatuck River, in Jennings County; and the Ohio River, Perry and Dearborn counties.

C. integrum (Say).—"Very much resembles *P. decisa*, the spire, however, is more elongated, and never truncated at the base, but always acute." (Say, 1821.) This has never convincingly been separated from *C. decisum*. Specimens identified as *C. integrum* are from the Calumet River in Lake County to the Big Blue River, Crawford County. A subspecies, *C. integrum obscurum*

(Lewis), is morphologically the antithesis of the typical form. The name has been seen applied to mollusks that were senile or distorted by trematode infestation.

C. subsolidum (Anthony).—Large, high-spined, of unusual thickness. There is ground for believing it an ecological variation of *C. decisum* or *integrum*. Indiana shells bearing the name are from the Wabash River, Wabash County; Elkhart River, Ligonier, Noble County; and the Muscatatuck River, near Millport, Washington County.

C. rufum (Haldeman).—This name has clung tightly in spite of the fact that all which Haldeman said of it is that it "is distinguished by the reddish color and entire apex, but it may be a variety of *P. decisum*." The reddish color is an individual variant in shells of many colonies of *Campeloma* and, further, appears in specimens on lake beaches subjected to weathering. Whether the apex is entire or not depends upon absence or prevalence of agents of mechanical erosion or chemical corrosion. Indiana shells determined as this species are from lakes of La Porte, Lake, La Grange, Starke and Kosciusko counties; Grassy Creek of Kosciusko County, Calumet River, Lake County, and the East Fork of the White River.

Family VALVATIDAE

The family is made up of small discoidal to turbate shells, the whorls rounded or varyingly carinate, the aperture circular. The operculum is continuously spiral. The foot is divided into lobes in front, rounded posteriorly. The tentacles are rounded, rather long, with the eyes at the inner sides of their bases. The gill is a feather-like organ, external and carried forward. Saw-like denticles border the folds and upper parts of the teeth.

Genus VALVATA Müller, 1774

The characteristics given of the family are those of the genus as it occurs in eastern North America.

Valvata tricarinata Say.—The most striking feature of this species is a series of strongly pronounced carinae, three on each whorl which follows the nucleus. It is probably present in every Indiana county although it was not observed in Franklin County by Moore and Butler. It feeds on minute algae among reeds and stones of shallow water, and it is to some degree tolerant of domestic sewage. The species appears to have been among the first of aquatic mollusks to reinvade the glaciated areas inasmuch as subfossil shells are fairly common in Pleistocene deposits. Six subspecies have been defined according to variation in number and position of carinae. They are of erratic occurrence, being present in some colonies as more or less rare individuals, and again constituting the entire colony. The following table is taken from F. C. Baker:

Upper, middle and lower carinae present	<i>tricarinata</i>
Middle carina absent	<i>perconfusa</i>
Upper and lower carinae absent	<i>mediocarinata</i>
Lower carina absent	<i>basalis</i>
Middle and upper carinae absent	<i>infracarinata</i>
Middle and lower carinae absent	<i>unicarinata</i>
All carinae absent	<i>simplex</i>

V. bicarinata Lea.—In typical forms, the shell is discoidal, the spire indented and the periphery rounded or slightly angled. The middle western forms more nearly resemble *V. tricarinata* than do these and have identically the same soft parts, whereas in this latter matter, *V. bicarinata*, according to its author's description, is decidedly different from *V. tricarinata*. Three modifications of carinae have been given names as subspecies, *connectans*, *normalis* and *perdepressa*. The species has been collected in Cedar Lake, Lake County, and in Lake Michigan on Indiana shores, *connectans* and *normalis* in the same localities, and *perdepressa* in Lake Maxinkuckee.

V. sincera Say.—A shell of rounded, elevated whorls covered with fine, crowded axial striae; usually pale brown. Found in both fast and standing water on stems of aquatic vegetation and on stones. The mollusks did not meet the attention of Call, Moore and Butler. Pleas reported it from Henry County and Daniels from Lake Michigan, La Porte and Lake counties.

V. lewisii Currier.—More depressed than *V. sincera*, the umbilicus wider and the axial striae less sharply defined. It was found in shallow water in mud and on vegetation. Observed by Daniels in Tippecanoe and Wawassee lakes, and Grassy Creek, Kosciusko County; Lake Maxinkuckee, Marshall County. It is probably this mollusk rather than *V. sincera* of the Maxinkuckee list.

Family AMNICOLIDAE

Mollusca consisting of several genera of small shells of marked variability, but with soft parts alike in that the snout is long, the tentacles slender with eyes at the outer margins of their bases; gill internal and verge exerted.

A key to the shell characters of the family has been supplied by Dr. Elmer G. Berry. It deals with all the Amnicolidae with the exception of the smaller species of *Somatogyrus*.

I. Shell with nuclear whorl above following whorls.

A. Umbilicus imperforate.

1. Whorls flattened.

a. Size large, 11 mm. in height *Bithynia*

b. Size small, 3 mm. in height *Pyrgulopsis*

2. Whorls inflated, size 5 mm. in height *Paludestrina*

B. Umbilicus perforate.

1. Attenuate, size less than 6 mm. in height.

a. Columella not reflected, whorls inflated *Amnicola lustrica*

b. Columella reflected.

(1) Whorls very inflated, aperture circular *Pomatiopsis cincinnatiensis*

(2) Whorls less inflated, aperture ovate *Pomatiopsis lapidaria*

2. Shell conical.

a. Whorls increasing gradually in size.

(1) Very small, 4 whorls, 2.5 mm. in size *Amnicola walkeri*

(2) Larger, 5 mm. in height *Amnicola integer*

b. Body whorl very large, size 9 mm. in height *Somatogyrus subglobosus*

II. Shell with nuclear whorl planorbid or sunken below the following whorls, size less than 6 mm. in height.

A. Shell with nuclear whorl coiled in the same plane with the following whorl, apex blunt.

1. Shell conical, size about 3.4 mm. *Amnicola limosa*

B. Shell with nuclear whorl sunken below the following whorl, apex truncated.

..... *Amnicola emarginata*

Genus BITHYNIA Leach, 1818

For the family, the shell is large. Elevated, the spire obtuse, aperture rounded and closed with a partially calcareous operculum which has a spiral nucleus altering to concentric. Central tooth trilobate, strongly dentate, lateral tooth broad and folded, marginals with simple folds. The generic name *Bulimus* Scopoli, 1777, has recently been revived for this mollusk, but has not been generally accepted.

Bithynia tentaculata (Linnaeus).—Of a bright golden or brown color, the dead shells conspicuous on Great Lakes beaches. The species is believed to have been introduced from Europe during the period of high activity in the lumber industry, but on the ground of findings in Pleistocene deposits, F. C. Baker considered the mollusk native to America and gave it the subspecific name of *magnalacustris*. The species lives in mucky areas bordering the Great Lakes and in some tributary streams. It is reported in Indiana from Lake Michigan near Millers, Lake County.

Genus AMNICOLA Gould and Haldeman, 1841

Shell small, conic, pyramidal or cylindrical; whorls seldom more than five, aperture nearly round, columella without callus deposit. Operculum paucispiral and marked with striae at right angles to the growth lines. Characters of radula and genitalia more distinctive as between species than shell characters. Wave lines on Great Lakes beaches are frequently defined by shells of the genus, reduced to shining pearliness, that have been cast ashore.

Amnicola limosa (Say).—Broadly conic, deeply sutured and, as fresh material, ranging from whitish-yellow to black, slightly umbilicate. As a single capsule, the egg is made fast to large objects, which often may be another mollusk; breeding season is midsummer. The shell inhabits shallow waters on stones or under them, on stems of water weeds or on sticks. Numbers can sometimes be scooped from the mud. *A. porata* (Say) is commonly listed either as a distinct species or as a subspecies, but as it intergrades with *limosa* it should be considered merely a form of it, being of greater relative diameter and with a more conspicuous umbilicus. Daniels found it in lakes of northern Indiana, but in every likelihood it occurs throughout the state.

A. limosa parva (Lea).—Lister here since Daniels reported it from lakes of Kosciusko and Starke counties, but it appears to be simply a small race of a genus none of whose members develop to a greater height than five or six millimeters.

A. lustrica Pilsbry.—Slender, smooth, the apex acute, the sutures deep and the aperture ovate. Found commonly in lakes, ponds and streams where there are heavy growths of weeds and masses of algae. It was not observed by Call, but Daniels found it in lakes of the northern part of the state. It is known also from Calumet River, Lake County.

A. walkeri Pilsbry.—A small race of about four whorls, deeply sutured, and living in thick growths of vegetation. Daniels reported it from Grassy

Creek, Kosciusko County. It is in his collection as from Calumet River and lakes of Kosciusko, Marshall and Steuben counties. A subspecies, *foxensis*, is described by F. C. Baker as "differing from typical *walker*i of the lakes in having a smaller, narrower umbilical opening and a relatively narrower form." He mentions it as probably in Indiana.

A. integer (Say).—This is the largest species of the genus in the United States and on anatomical grounds it has been held to be a subgenus or a genus to itself. As nearly all the named species of *Amnicola*, unlike several other freshwater gastropods, have peculiarities of anatomy of their own, this course is scarcely justified. The mollusk lives in streams rather more than in lakes. Call remarked it at Lawrenceburg, Dearborn County; Daniels in Lake Michigan and at Upton, Posey County. It has been collected also in Lake James, Steuben County; Wabash River, Miami County, and Blue River, Henry County. For many years, Say's name was ignored and *A. cincinnatiensis* Anthony used in its place.

A. emarginata (Küster).—Narrowly conic, the shell chiefly characterized by a broad, flattened apex. Commonly an inhabitant of relatively deep water. It has been taken in Lake Michigan, Lake County, and in the Wabash River at Grand Chains, Posey County.

Other species of *Amnicola* which possibly occur in the state are: *A. pilsbryi* F. C. Baker, related to *A. walker*i, but more globose and having peculiarities of the radula; *A. leightoni* F. C. Baker, "bulbous, conic, turreted and widely umbilicated," which, so far, has been seen only in Pleistocene deposits; *A. precursor* F. C. Baker, also a Pleistocene mollusk; *A. oneida* F. C. Baker, akin to *A. lustrica*, and observed by Baker in Michigan material.

Genus PALUDESTRINA D'Orbigny, 1840

Shell very attenuate, the aperture round, operculum paucispiral. Body narrow, the foot rounded behind, penis trifid. The central tooth has three lobes, the lateral tooth has six or seven relatively coarse denticles, the marginals many fine ones. One species of the genus occurs in Indiana.

Paludestrina nickliniana (Lea).—Colonies rare, the numbers of individuals usually very many. The mollusk lives on water cress and other aquatic vegetation in springs, brooks and small lakes. It is reported by Daniels as from Berry Lake, Lake County. His collection contains specimens from Little Kankakee River and a spring near Michigan City, both in La Porte County.

Genus PYRGULOPSIS Call and Pilsbry, 1880

Small, pupiform, slightly shouldered and smooth. Operculum spiral, marked with crowded growth lines. Radula compact, all teeth with numerous denticles. One species is known to Indiana.

Pyrgulopsis wabashensis Hinkley.—Found by Hinkley in the Wabash River, Grand Chains, Posey County, and seen nowhere else in the state, although probably it lives also in the Ohio River and has escaped observation there because of its small size and inconspicuous color.

Genus *SOMATOGYRUS* Gill, 1863

A group of small, thick shells which are unsculptured except for microscopic punctations on the nuclear whorls; aperture elliptical, columella very much thickened. Operculum paucispiral. Tentacles short, flattened; central teeth wing-shaped, upper parts of laterals squarish and with a few denticles, marginals multicuspid; penis bifid.

Somatogyrus subglobosus (Say).—The largest species of the genus. The spire is more elevated than in most of the other forms, the shell translucent, of a creamy white color. Say gives the "North-western Territory" as the locality, and it seems probable that the specimens he saw were gathered as drift on the shores of the Ohio River. His *Melania isogona*, 1829, and *M. integra*, 1840, reported upon at New Harmony, are synonyms. Distribution is throughout Indiana.

S. currierianus Lea.—"Apex rather prominent. Apical whorl rather low, nearly flat above, convexly rounded, but not constricted by the suture and not everted." (Walker, 1915.) Found in the Ohio River at Elizabethtown, Hardin County, Illinois, and probably occurring in the river where it borders Indiana.

S. depressus Tryon.—A small form with very short spire and a heavily callused columella. Shells credited to this species have been collected in the Wabash River at Grand Chains, Posey County; the White River, Gibson County, and Flat Rock Creek, Bartholomew County.

S. strengi Pilsbry and Walker.—Decidedly globose, the aperture rounded below, greenish. Taken in the Wabash River at Grand Chains.

S. trothis Doherty.—Very small, the body whorl greatly inflated, altitude greater than the diameter. Specimens collected in the Wabash River just below the old dam at New Harmony have been determined as this species.

Genus *POMATIOPSIS* Tryon, 1862

Small, elongate, five to seven millimeters in height, reddish-brown and translucent in young specimens, grayish-brown and opaque in old. Operculum much as in *Amnicola*. Rostrum projecting beyond the short, rather thick tentacles; the foot short. Radula simple, the teeth with few folds or denticles.

Pomatiopsis lapidaria (Say).—The gills are identical with those of *Amnicola*, but the mollusk is to be found under wet logs, in grass at a distance from water and in flood-plain debris as well as in pools and on mud flats of brooks. A difference of opinion exists as to whether the mollusk should be termed terrestrial or amphibious. It occurs throughout Indiana.

P. cincinnatiensis (Lea).—Differing from *P. lapidaria* in being smaller, wider with relation to height, and in having a more distinct umbilicus. It has the same curious habits of that species. Observed in Henry County by Pleas and in La Porte County by Daniels.

Family *PLEUROCERIDAE*

Shells usually thick, varying much in shape even within the same species;

smooth or sculptured, pigmented with revolving stripes or lacking such coloration, low-spined or high-spined. Operculum chitinous, differing to some extent as between genera and, in instances, between species of a genus. Edge of mantle smooth, eyes on outward sides of bases of tentacles; female with sinus on right side of foot; male lacking copulatory organ; radula fairly distinct in three of the genera, but of small service in distinguishing species.

The anatomy of the Pleuroceridae is so nearly alike among the genera that hopes of differentiation by means of dissection rests upon minutiae still to be worked out. Variation in the operculum of northern forms is in size and the position of the nucleus. Such material radular distinctions as exist are in the lateral teeth. Recognition of the genera depends now as in the past upon shell characters. The key outlines the characteristics which are most likely to meet the student's eyes. Measurements are of Indiana specimens.

1. Shell large in size (length 30-40 mm.) 2
 Shell medium to small (length less than 30 mm.) 3
2. Elongate, large (length up to 40 mm.); spire very loosely coiled; plicate to nodulous in a single species, smooth in others; periphery carinate to nodulous, sometimes channelled, aperture awl-shaped *Pleurocera*
 Broadly conic to nearly cylindrical (length up to 30 mm.); spire usually tightly coiled; smooth, obscurely plicate to strongly nodulous; aperture ovate to elongate-ovate *Lithasia*
3. Aperture ovate 4
 Aperture subrhomboidal 5
4. Medium size (length 10-18 mm.); shell heavy, pyramidal; spire tightly coiled and keeled *Anculosa*
 Smaller (length 10-12 mm.); pyramidal or conic; spire short; smooth to spirally keeled *Nitocris*
5. Medium size (length up to 15 mm.); narrowly conic; spire tightly to loosely coiled; surface without sculpture *Goniobasis*

Genus PLEUROCERA Rafinesque, 1818

Shells elongate, early whorls very loosely coiled, aperture awl-shaped, sculpture if any consisting of revolving striae or more or less deep sulcations on maturing whorls; plicate in one species. Operculum with nucleus near the left margin; radula small, compact, suggesting degeneration. Food is algae obtained from mud in which most of the species of the genus live.

Pleurocera acuta Rafinesque.—This is the slender, elongate form occurring in the upper Wabash River, some of its tributaries and lakes with which the river is connected; the Maumee and branches of the Lake Erie drainage basin. It is absent, seemingly, from the White River and its forks, and also from the Whitewater River. The shell is the *P. subulare* (Lea) of early Indiana lists.

P. canaliculatum (Say).—Typical examples have a rounded periphery, usually with a sulcation just beneath the suture on final whorls. It is a stout, heavy mollusk. It appears first in the Wabash River a few miles above Lafayette, Tippecanoe County, becomes the dominant form at about Terre Haute and is especially common at New Harmony. It is apparently the only species of the genus in the Ohio River bordering the state, and occurs well up-stream in forks of the White River. *P. elevatum* (Say) of Call and Daniels is this species.

P. canaliculatum undulatum (Say).—The mollusks that Say described have a semi-nodulous periphery in the adult stage, and are comparatively rare, the prevailing phase having a carinate or angulate periphery. It occurs in the Wabash River in places with *canaliculatum* typical, and possibly there represents only an individual phase. The subspecies (or form) is common in the Wabash River at Grand Chains. Here and in the channel known as Fox River are shells the peripheries of which are nodulous. They have been identified as *P. moniliferum* (Lea), but appear to be only variants or reversions of *P. canaliculatum undulatum*. *Pleurocera* taken in the Wabash River at two localities was in these proportions:

2 mi. above Lafayette	No.	%	Independence	No.	%
<i>acuta</i>	28	15.1	<i>acuta</i>	59	22.4
<i>canaliculatum</i>	29	15.7	<i>canaliculatum</i>	45	17.1
<i>undulatum</i>	68	36.7	<i>undulatum</i>	47	17.8
indeterminate young	60	32.4	indet. young	112	42.6
	185			263	

P. alveare (Conrad).—A conic shell of plicate sculpture, rare in the genus, the lower part of the plicae developing into peripheral nodes. Occurs in the lower Wabash River, Gibson and Posey counties. Not observed by Call.

Genus LITHASIA Haldeman, 1840

Shell usually thick, nodulous in the case of two species occurring in Indiana, smooth in the third; aperture large and produced, the columella in old individuals thickened with callus at top and base. Nucleus of operculum very tightly coiled, and indicating obsolescence. Soft parts the same as in other genera of the family, the radula lacking special characteristics. *Angitrema* Haldeman, 1841, is a synonym.

Lithasia armigera (Say).—Heavy, ornamented with nodes on the periphery, resembling *Pleurocera alveare*, but wanting plicae and having a differently shaped aperture. Known to occur in the Ohio River as far up-stream as Evansville; in the Wabash River from its mouth to Mt. Carmel, Illinois. The citation from Lake Maxinkuckee is an error. Shells from the Wabash River of this species which had notched outer lips were made monotypes of the genus *Meseschiza* by Lea in 1864. The notches are accidental breaks in the thin shell wall at the periphery.

L. verrucosa (Rafinesque).—The tubercles are in rows over the whole disk of the body whorl, being modifications of revolving striae. The species was described by Say as *Melania nupera* from specimens he found in the Wabash River at New Harmony. It apparently does not go farther up-stream than this point. It has been observed by A. C. Billups in the Ohio River at Lawrenceburg, Dearborn County, and this would seem to be the limit of its up-stream range in that stream.

L. obovata (Say).—The mollusk takes several confusing forms, from delicate and slender to thick and low-spired. Almost always smooth, but occasional specimens revert to the nodulous characteristics of other species of the

genus. The synonymy is large. Forms which have been reported as inhabiting Indiana waters are *Melania depygis* Say, *Goniobasis infantula* Lea and *G. louisvillensis* Lea. Known from the Wabash River from Vincennes downstream; Ohio River, Vanderburgh County to Clark County; Big Blue River, Crawford County, and Big Indian River, Harrison County.

L. obovata biconica Pilsbry.—This is a large, heavy mollusk, the type locality of which is the Wabash River, Gibson County, Indiana. Known elsewhere only from the Kentucky River, Kentucky.

Genus NITOCRIS H. and A. Adams, 1858

Shells varying from depressed to pyramidal; smooth or sculptured with raised revolving lines. The operculum is small, neo-melanian; in instances lacking any sign of spiral nucleus and developed into the shape of a ribbon. Species of the genus are placed under *Anculosa* in the older faunal lists, but their radulae resemble those of *Pleurocera*.

Nitocris trilineata (Say).—Small, flattened, commonly, but not always, with three revolving stripes. The type locality is Falls of the Ohio, and the shell has been seen in that stream from Cincinnati down. It feeds on algae on stones in fast water. Specimens with fine, sharp ridges were named *Anculotus costatus* by Anthony, but they merge into typical *N. trilineata*.

Genus ANCULOSA Say, 1821

Shell thick, subglobose, short-spined, the young with revolving keels. Pigmented with bands or not, these sometimes broken into squares or oblongs. Operculum neo-melanian. The lateral teeth of the radula have a long peducle and a broad, cleaver-like overlap.

Anculosa praerosa (Say).—Named from shells taken at the Falls of the Ohio. It lives on algae-covered rocks in fast and heavy currents, for the most part in the larger streams. The range in the Ohio River is from Scioto County, Ohio, to Pope County, Illinois. It inhabits the Wabash River at Grand Chains, Posey County, and the Big Blue River, Crawford County.

Genus GONIOBASIS Lea, 1862

A family of many species, those occurring in Indiana being elongate and thin to pyramidal and thick, lacking all sculpture except growth lines and revolving ridges. Young carinate, the carinae overlaid by shell material during the maturing stage. Operculum small, the nucleus varying in position. It is an aid in the differentiation of species, which is not true of the radula, a well-developed organ but in *Goniobasis* lacking special characteristics.

Goniobasis livescens (Menke).—Elongate to somewhat ventricose, usually loosely coiled in sheltered situations, tightly coiled in fast-moving water or at exposed localities of lakes. Operculum tending to roughen in old specimens, the nucleus so close to the left margin that it is frequently lost by abrasion. *G. livescens* inhabits the Wabash River, numerous branches and lakes of the drainage; the Maumee River and tributaries, and the St. Joseph River of Lake Michigan and tributary waters; probably also in that part of Lake Michigan which borders Indiana. *G. cubicoides* (Anthony), assigned to the Wabash,

is merely a phase of this species wherein the juvenile carinae persist as keels into adult life. It involves no more than occasional individuals of a colony. *G. brevispira* (Anthony), listed by Blatchley and Daniels, is a form of *livescens* whose early whorls are tightly coiled. Variability is responsible for many synonyms in this species.

G. semicarinata (Say).—A shell of as simple characters as *livescens*, mainly distinguished from it by its somewhat triangular operculum the nucleus of which is much nearer the center and more loosely coiled. An inhabitant of the two forks of the White River and branches thereof, the Whitewater River, the upper parts of the Big Blue River and probably other streams of southern Indiana. *G. pulchella* (Anthony) and *interlineata* (Anthony) are synonymous. Christy Creek, Indiana, is given as the type locality for the latter.

G. indianensis Pilsbry.—This is a striate form which occurs in Big Blue River, Crawford County. In certain parts of the stream it is associated with *G. semicarinata*, and may be a peculiarly sculptured mutation of that species.

G. intersita (Haldeman).—A strongly plicated shell the type locality of which is given as Swan Creek, Indiana. Specimens came to Haldeman from Mrs. Say. The species has not been rediscovered or a Swan Creek of Indiana traced. There is reason to suspect that *intersita* is *G. costifera* (Haldeman), known from Hardin County, Illinois, and that Swan Creek belongs to that state rather than to Indiana.

Bivalves

For Indiana, Stein (1881) listed sixty-four species of mussels as based on our present evaluation of the naiades. Call (1900) listed about seventy which were distributed among three genera. The present list contains seventy-six species comprising thirty-three genera which are arranged alphabetically within their proper families and sub-families. The following discussion of the species is submitted not as a substitute for the work of Call (1900), Blatchley and Daniels (1903) and Daniels (1914), but rather as an addition which recent investigations make possible. To anyone not familiar with freshwater mussels, Call's plates and descriptions, to which repeated references will be made, serve as an indispensable aid. In the treatment of the species care has been taken to avoid repeating information already given in the works of these three men.

The Spæriidae are considered immediately following the mussels.

Family MARGARITANIDAE

Only a single species in Indiana belongs in this family which is distinct both in shell structure and anatomy. Originally, Say placed *Cumberlandia monodonta* in the genus *Unio*, but Ortmann (Nautilus 26:13-14) studied its anatomy and showed that it belongs to this family by virtue of the peculiar structure of the water tubes in the gills.

Genus CUMBERLANDIA Ortmann, 1912

Cumberlandia monodonta (Say).—This is a rare species in Indiana and has been reported only from the region of the Grand Chains of the Wabash

River. As suggested by Call (1900: 527) there is some superficial resemblance between this species and *Ligumia recta latissima*. The lack of lateral teeth and the characteristic dull black epidermis will readily separate the former from the latter.

Family UNIONIDAE

As in the Margaritanidae, the gill structure is of considerable importance as a family character. In contrast to the Margaritanidae, the Unionidae have the gills divided into septa and water tubes. Each of the subfamilies in the following arrangement of the species is based in turn on the modifications of the gill structure. The first set, *Amblesma* through *Uniomerus*, belongs to the subfamily Unioninae. The species are short-term breeders, the water tubes are not divided into compartments, and the whole gill (usually all four) becomes marsupial. The genera *Alasmidonta* through *Strophitus* belong to the Anodontinae. The members of this subfamily are long-term breeders, the water tubes of the outer gills are divided into three compartments with the central one used as an ovisac. The last set of genera, *Actinonaias* through *Truncilla*, belong to the Lampsilinae, which are also long-term breeders. They have simple water tubes with only the posterior portion of the outer gill serving as an ovisac for the developing glochidia.

Genus AMBLEMA Rafinesque, 1819

Amblesma costata Rafinesque. (Call, plate 13).—Found widely distributed throughout the state. It is reported from: headwaters of the Wabash and White Rivers, the St. Joseph northeast of Fort Wayne, the Maumee, the Big Blue and the Kankakee rivers. This species is referred to as the "Three-ridge" or "Blue-point" by clammers and is considered a valuable shell in the button industry. Usually *A. costata* inhabits headwaters and streams of small or medium size, while in the large rivers the following species replaces it.

A. peruviana (Lamarck). (Call, plate 14).—In Indiana this species is much less common than *A. costata*. In general appearance it is similar to *costata* and can usually be separated by its heavier and more anterior beaks. Ecologically the two species (if they can be considered good species) occupy the extremes within a drainage system, i.e. *A. costata* is found in the smaller headwater streams while *A. peruviana* is restricted to the lower reaches of the system of large proportions.

Genus CYCLONAIAS Pilsbry, 1922

Cyclonaias tuberculata (Rafinesque). (Call, plate 49).—The common name applied to this shell by the clammer is "Purple Warty-back," a name which is very descriptive. This species inhabits most of the larger streams in the state. In passing from the mid-portion of a large stream such as the Wabash into the region at and below Terre Haute one finds that this species has coarser pustules. Formerly the name *granifera* was applied to the large-river phase of *C. tuberculata*. It is now known that *granifera* is merely an ecological form.

Genus ELLIPTIO Rafinesque, 1819

Elliptio dilatatus (Rafinesque). (Call, plate 16).—This species is among the most common in the state. For some unknown reason Call (1900, 450)

suggests that this is a large river inhabitant. In plotting the distribution of it throughout the Wabash Drainage it is obvious that it ranges throughout the system and, if anything, is apt to be most abundant in streams of smaller size. A list of the localities from which *E. dilatatus* has been reported would be altogether too long to be included here. Suffice it to say that it inhabits practically all the streams in the state.

E. crassidens (Lamarck). (Call, plate 63).—This relatively large, thick-shelled, triangular *Elliptio* with its purplish nacre is far less common than *E. dilatatus*. It is found rarely in the larger rivers that drain the southern portion of the state. There are records from the following rivers: Wabash (Grand Chains, Terre Haute), White River (Hayesville, Washington, Shoals and Rockford), and the Ohio River at Vevay.

Genus FUSCONAIA Simpson, 1900

Fusconaia ebenus (Lea). (Call, plate 58).—This high grade button shell is generally known as the "Niggerhead." It is a species found only in streams of considerable size and is never associated with a creek or small river environment. In Indiana it is reported from the Ohio River and the wider, larger portions of the Wabash and White rivers.

F. flava (Rafinesque). (Call, plate 61).—There is the same relation between *F. flava* and *F. undulata* as between *Amblema costata* and *A. peruviana* in that *F. flava* is common in headwaters of drainages and is replaced in the larger or down-river portion by *Fusconia undata*. Numerous records are available to establish *F. flava* as common to all of the smaller streams throughout Indiana. It is at times found in lakes, but is restricted to those which have a certain amount of river influence; it is not common to any of the land-locked lakes of the glaciated portion of the state.

F. subrotunda (Lea).—In Indiana this species is confined to the Ohio and tributaries of it. Records show that it is found in the Wabash and Tippecanoe rivers where it occurs in the larger portions. In the headwaters the compressed form *kirtlandiana* appears. Only a single record (Eel River, Wabash County) is available for this headwaters form. The species does not occur in the Kankakee or Maumee drainages or in any of the rivers of the northern part of the state. The bright rays of younger specimens will help to separate this species from *F. ebenus* to which it bears some resemblance.

F. undata (Barnes). (Call, plate 60).—Found in the large rivers of the state. It is recorded from the Ohio, White and Wabash rivers. Formerly it was called *trigona* and the relation between this species and *F. flava* is indicated by the fact that some zoologists still refer to large, down-river forms of *flava* as *F. flava trigona*. The range of *F. flava* in the smaller streams of headwaters and *F. undata* in the larger portions of rivers is well established, but there are zones of intergradation which often make it difficult to determine the taxonomic status of specimens taken in such intermediate zones within a drainage system.

Genus LASTENA Rafinesque, 1820

Lastena lata (Rafinesque). (Call, plate 68).—Ortmann (1915: 106-108) has studied the anatomy of this interesting naiad and has come to the conclusion that the genus belongs to the sub-family Unioninae and not to the Anodontinae as was previously supposed. Call (1900: 534) reasoned that the lack of well developed teeth on the shell of necessity made *Lastena* a member of the Anodontinae. Ortmann's work on the anatomy of this species conclusively indicates its relationship to the genus *Elliptio*. It is a rare shell throughout its range. In Indiana it has been recorded in the Ohio, Wabash, Tippecanoe and White rivers.

Genus MEGALONAIAS Utterback, 1915

Megaloniaias gigantea (Barnes). (Call, plate 15).—As the name implies, this is one of the largest of mussels. It is readily distinguished from the species of *Amblema* by the ornamental patch of tubercles located on the disc just below the umbones. It inhabits large rivers and in Indiana it has been recorded for the Ohio, Wabash, and White rivers.

Genus PLETHOBASUS Simpson, 1900

Plethobasus cicatricosus (Say). (Call, plate 55).—This is a relatively rare species in Indiana. It has thus far been found only in the Wabash River. A species, *cicatricoides*, described from a specimen labelled "Wabash River" by Friener in 1911, is now considered merely a deformed or "unique" specimen.

P. cooperianus (Lea). (Call, plate 42).—In Indiana this shell is confined to the Ohio and lower portion of the Wabash rivers. It is rare, and is most commonly confused with *Quadrula pustulosa*. The reddish-brown cast of the epidermis, the more extended posterior end, and the characteristic high pustules will help to separate *P. cooperianus* from *Q. pustulosa*.

P. cyphyus (Rafinesque). (Call, plate 52).—Of the three species of *Plethobasus* in the state, this is the most common. However, all the members of the genus are to be considered relatively rare and one is apt to find only a few specimens along with literally thousands of other forms. The range of *P. cyphyus* is consequently not well defined, although it is known to be a species (like the others) usually associated with large streams. It has been recorded from the Ohio, Wabash, White, Tippecanoe and Kankakee.

Genus PLEUROBEMA Rafinesque, 1819

Pleurobema clava (Lamarck). (Call, plate 62).—Of the species of this genus in Indiana, this is one of the smallest. It is usually found in the smaller rivers and is widely scattered throughout the state. There are records of occurrence in the Wabash, White, Blue, Maumee, Tippecanoe, Eel, Mississineva, St. Joseph, Whitewater and St. Mary rivers. Records from Flat Rock Creek and Sugar Creek (both in Shelby County) emphasize that this is a species also adapted to a small stream environment.

P. cordatum (Rafinesque). (Call, plate 57).—Much confusion formerly existed concerning the relationships of this species and various forms of it which have in the past been recognized as distinct species. The late Dr. Ortmann has studied the group carefully and has shown that *cordatum* tends to vary in two directions. On the one hand, it becomes higher with an increasingly shortened posterior end. In this direction we get a series of forms that are named progressively as the specimens get higher in this order: true *cordatum*, then *cordatum catillus* (Call, plate 59), then *cordatum plenum*, and finally the highest forms are called *cordatum pyramidatum*. This series comprising the main species and its forms are associated with streams of comparatively large size. On the other hand, when *cordatum* (the typical form) loses its sinus, becomes rounded and tends to assume an elongated posterior end, then the name *cordatum coccineum* (see Call, plate 56) is applied. This form differs ecologically from the true *cordatum* and the higher forms in that it inhabits streams which are considerably smaller, getting well into the headwaters of the larger rivers. Distributionally, it is of interest to note that the true *cordatum* and the high forms are largely restricted to the big rivers in the southern portion of the state, such as the Ohio, White and Wabash. *P. cordatum coccineum*, however, is found throughout the state and continues northward into the Maumee, St. Joseph and Kankakee rivers.

Genus QUADRULA Rafinesque, 1820

Quadrula cylindrica (Say). (Call, plate 29).—Among the mussels of Indiana this species is one of the most easily recognized. It inhabits both large and small streams, but it is largely restricted to the Ohio and rivers draining into it. In the northern part of the state *Q. cylindrica* has crossed into the Maumee River drainage. The crossing of this species and other typical Ohio Basin forms into the St. Lawrence drainage across the low divide between the Maumee and Wabash drainage systems is good evidence that in the past there was a confluence between these rivers. Walker, Ortmann, Goodrich, van der Schalie and others have earlier referred to this important junction as one of the avenues by which many species have reached Lake Erie and the streams flowing into it.

Q. metanevra (Rafinesque). (Call, plate 28).—This easily identified mussel bears the common name of "Monkey-face." It is a common shell in Indiana and is associated particularly with the larger rivers. It is recorded from the Ohio, Wabash and White rivers.

Q. nodulata (Rafinesque). (Call, plate 44).—Superficially this species resembles *Q. pustulosa*. The lack of the green color band usually found across the umbonal region of *Q. pustulosa* and the presence of the nodules which are restricted to a double row in *Q. nodulata* are characters which will help to identify the species. It is usually found only in larger rivers and has been reported from the Ohio, Wabash, White and Blue rivers. Call (1900: 487) reports its occurrence in the Kankakee. It has not been reported from north-eastern Indiana.

Q. pustulosa (Lea). (Call, plates 45, 46 and 47).—The general shape

and the pustules covering the valves of this species readily distinguish it. However, the sculpture is often poorly developed (particularly in young specimens); a condition which increases the difficulty of determination. It is associated with larger streams and has been found in practically all of the important rivers in the state.

Q. quadrula (Rafinesque). (Call, plate 48).—A broad smooth furrow across the pustulose valves of this species readily identifies it. It is a good bottom shell and is found in practically all of the larger streams in Indiana. It is known to clammers by the picturesque name of "Maple-leaf." The *Q. fragosus* of Conrad is certainly only a form of *Q. quadrula* and need not be discussed as a distinct species.

Genus TRITOGONIA Agassiz, 1852

Tritogonia verrucosa (Barnes). (Call, plate 26).—In Indiana this species is found only in larger rivers of the southern part of the state which drain towards the Ohio. This species is unusual in that it is sexually dimorphic which is quite unusual in members of the Unioninae. Males are as a rule short with the ribs on the posterior slope well developed, while the females are attenuate posteriorly, laterally flattened and the ribs on the posterior slope are poorly developed.

Genus UNIOMERUS Conrad, 1853

Uniomerus tetralasmus (Say). (Call, plates 66 and 67).—This is a relatively rare species in Indiana. The characteristic concentric beak sculpture serves well as an aid in identification. It has been recorded (Call, 1900: 519) for the Ohio and Wabash rivers. Daniels (1914: 650) gives Montour's Pond in Knox County for the locality of a form known as *sayi*. With more intensive collecting *U. tetralasmus* will probably be found inhabiting ponds, abandoned canals, etc. This species is unique in its ability to survive by aestivation in ponds that may be dry for from three to six months (see van der Schalie, 1940: 137-38).

Genus ALASMIDONTA Say, 1818

Alasmidonta calceolus (Lea). (Call, plate 68, figs. 4-6).—This relatively small species is common in creeks all over the state. Occasionally specimens are found in large streams or in lakes, but such environmental conditions are not typical for the species. When occasionally found in lakes the shells become small and stunted; while in larger streams the few specimens found are often considerably larger than similar forms of creeks.

A. marginata (Say). (Call, plate 70).—This is a common shell in headwaters of streams throughout the state. It is usually not present in larger rivers such as the Ohio, although at times occasional stragglers turn up in larger streams. However, on the whole, the larger populations inhabit what may be called small-river conditions. Records such as: Eel River, branch of Blue River, Salamonie River, etc., emphasize its predilection for smaller streams. It is not common to lakes, and if found in such a body one will invariably find that it is associated with what should be termed a river-lake, i.e., a lake with strong river influence.

Genus ANODONTA Lamarck, 1799

Anodonta grandis Say. (Call, plate 77).—Because of its ability to live in a wide variety of habitats this is one of the most common species of the state. Its wide range of habitat has resulted in an equally large variation in size and shape. There is a swollen form called *A. g. footiana* adapted to "floating" on soft mud and peat in lakes — an environment in which other species would bog down and smother. In rivers this species is less swollen and usually more attenuate and it is to these forms that the typical *A. grandis* name is applied. In larger streams the shells often become huge so that the form name *A. g. gigantea* may be used to distinguish them.

A. imbecillis Say. (Call, plate 73).—The straight hinge line with its striking lack of swollen beaks readily separates this *Anodonta* from the other two species common to Indiana. F. C. Baker suggested that *imbecillis* should be placed in a new genus *Uterbackia* because it supposedly passed through its life-history without parasitism. Subsequent research by Miss Tucker under the direction of Professor Van Cleave showed conclusively that the green sunfish (*Lepomis cyanellus*) served as host to the glochidia of *A. imbecillis*. As in other parts of its range, the *A. imbecillis* in Indiana, although found in practically all of the drainage systems in the state, is rather sporadic in its distribution. The tendency for this species to live in ponded regions such as occur above dams, at outlets of lakes, quiet mud banks in bends of rivers, etc., may partially explain the discontinuity in its distribution pattern.

A. suborbiculata Say (Call, plate 78).—In Indiana this species is not at all common nor widespread. It is reported (Call, 1900: 533) from the Wabash River in "muddy bayous and small lakes left by the changing of the river's course." Daniels (1914: 649) reported it from the White River at Rockford.

Genus ANODONTOIDES Simpson, 1898

Anodontoides ferussacianus (Lea). (Call, plate 76).—In Indiana as elsewhere this species is most commonly found in creeks and small headwater streams. It ranges widely and can be found in practically all of the river systems of the state. There is considerable variation in the shape and size of the shells from the various habitats. This variation has resulted in the application of several form names, of which *subcylindraceus* is one of the most common. The tendency in the past has been to over-emphasize the importance of such names.

Genus ARCIDENS Simpson, 1900

Arcidens confragosus (Say). (Call, plate 69).—This very striking shell with prominent tubercles across its umbones has been reported only from southern Indiana. As suggested by Call (1900: 521) it is very similar in distribution to *Anodonta suborbiculata*. The records available limit *A. confragosus* to the lower portion of the Wabash and White rivers where it shows a preference for a muddy environment in deep water.

Genus *LASMIGONA* Rafinesque, 1831

Lasmigona complanata (Barnes). (Call plate 71).—This rather large plate-like species is known commonly as the "White-Heel-splitter" or "Elephant's Ear." It is abundant mainly in streams and canals throughout the state. It has crossed from the Wabash into the Maumee River drainage, but according to Wilson and Clark it is not a particularly common shell there. It is mainly a species of larger streams and is not often found in creeks. Usually it lives on a muddy bottom where there is little current.

L. compressa (Lea). (Call, plate 24).—Of the three species of *Lasmigona* in Indiana this one can be distinguished by its hinge tooth structure, with its large and well developed interdentum and the presence of thin but definite lateral teeth. Ecologically it is a species of small streams although an occasional specimen is at times found in rivers. As a rule, *L. compressa* may be found in a stream too small to harbor any other species. It is widely distributed in Indiana and has been recorded from practically all of the drainage systems.

L. costata (Rafinesque). (Call, plate 72).—The rugose nature of the posterior slope of this species is a rather useful aid in identifying it. In Indiana *L. costata* inhabits the headwaters of most of the streams. Occasionally it is found in the larger portions of a river, but it is not usually common there. The ability of this species to adapt itself to a wide range of ecological conditions partly accounts for its unusually wide distribution.

Genus *SIMPSONICONCHA* Frierson, 1914

Simpsoniconcha ambigua (Say).—In Indiana, as elsewhere in its range, this species is very sporadic in distribution. Thus far the records in Indiana limit *S. ambigua* to the White and Wabash rivers. B. Shimek (*Nautilus*, 2: 114) as early as 1888 pointed out that this small species is often found under large slabs of limestone in soft mud. Some years later (1915) A. D. Howard (*Nautilus*, 29: 6-8) showed experimentally that it completes its larval development on the mud-puppy (*Necturus maculosus*). The environmental conditions reported by Howard were similar to those reported earlier by Shimek, but the former found a mud-puppy under the same flag-stone beneath which the infected *Simpsoniconcha* was taken.

Genus *STROPHITUS* Rafinesque, 1820

Strophitus rugosus (Swainson). (Call, plate 75).—The heavier concentric beak sculpture, the thicker shell with usually a salmon nacre, and the rudimentary pseudocardinal teeth, are characters which will aid in separating this species from *Anodontooides ferussacianus* which somewhat resembles it. In Indiana, *S. rugosus* is found throughout the state in practically every drainage. As a rule, it is most abundant in the headwaters and is relatively rare in large rivers. It is found also in lakes, but only in those that have some degree of stream influence.

Genus ACTINONAIAS Fischer and Crosse, 1893

Actinonaias carinata (Barnes). (Call, plate 41).—This species, commonly known as the "mucket," is one of the most useful and desirable shells for the manufacture of pearl buttons. It inhabits mainly large rivers and is found in all of the major drainage systems in the state. As a rule, it prefers gravel bars in a current. It is not found in lakes; an observation that has an important bearing in zoogeographical studies.

A. ellipsiformis (Conrad). (Call, plate 20).—Earlier reports on the mussels of Indiana suggest that this species is found widely scattered throughout the state. In the light of more recent work there is reason to believe that actually *A. ellipsiformis* is found only in the northwestern portion where it inhabits the St. Joseph River and the headwaters of the Kankakee River drainage. There is a record for "Lake Maxinkuckee," but this is obviously in error since Evermann and Clark (1917) failed to find it there. This species is abundant in small headwater streams and is rather uncommon in large rivers. It is at times confused with old specimens of *Micromya iris*, but the thickened shell and heavy hinge teeth, the lack of prominent sculpture on the beak, the mass of fine green rays concentrated just anterior to the posterior ridge, and the tendency to have a wide but definite angle along the posterior ventral margin—these are all characters that will help to separate *A. ellipsiformis* from *Micromya iris*.

Genus CARUNCULINA Simpson, 1898

Carunculina glans (Lea). (Call, plate 65, figs. 5-7).—This small species is common to most of the streams in Indiana. Records show that although it is at times found in larger rivers such as the Wabash and White rivers, it is mainly an inhabitant of smaller rivers throughout the state. Call (1900: 517) has given a useful table to show the characters that separate *C. glans* from *C. parva*. The more globose form, the smoother and rayed epidermis, and particularly the purple nacre will help to distinguish *C. glans* from *C. parva*.

C. parva (Barnes). (Call, plate 65, figs. 1-4).—Like *C. glans*, this species is rather widely distributed throughout the rivers of Indiana. Although both *C. parva* and *C. glans* are found in the northern part of the state, both species seem to be most common in the headwaters of the streams of southern and central Indiana that drain to the Ohio River. The greenish or gray epidermis, with its lack of rays and its fine but prominent lines of growth, the elliptical (rather than oval) outline of the shell, and the white nacre—these are essential characters which help in separating *C. parva* from *C. glans*.

Genus CYPROGENIA Agassiz, 1852

Cyprogenia irrorata (Lea). (Call, plate 43).—This species is easily identified through its peculiar green, mottled epidermis, as well as by the presence of nodules on its outer surface. In Indiana, as elsewhere in its range, it is mainly a species of large rivers and is confined to the Ohio, Wabash and White rivers, with their larger tributaries.

Genus DYSNOMIA Agassiz, 1852

Dysnomia flexuosa (Rafinesque). (Call, plate 64).—In earlier lists this species is called *D. foliatus* (Hildreth). A re-examination of the Rafinesque species by Ortmann and Walker (1922: 70-71) indicates that *flexuosa* has priority over *foliatus* by eight years. In Indiana this species is relatively rare and has only been reported from the Ohio River and the lower portion of the Wabash River in Posey County. The "leaf-like" appearance of the females is very striking.

D. personata (Say). (Call, plate 33).—Like *D. flexuosa* this species is a rare shell in Indiana. It is found only in the lower reaches of the Wabash and White and invades these streams from the Ohio River where both species have their center of distribution. *D. personata* seems to be a transition form and closely resembles *D. sulcata* which will be mentioned below.

D. perplexa (Lea). (Call, plate 34).—This species and its form *rangiana* are quite well represented in the Ohio, Wabash and White drainages. The typical form, *perplexa*, inhabits the larger rivers and tends to have the nodules or "bosses" on the posterior slope well developed; the form *rangiana* is more common in small rivers and often these same nodules or "bosses" are small or entirely absent. *D. perplexa rangiana* has crossed over from the Wabash drainage into the Maumee River system and has gotten into Lake Erie where an occasional specimen is found.

D. sampsoni (Lea).—This is a rare shell in Indiana. It has managed to get established only in the lower Wabash River and may be present in the lower portion of the White River. Call (1900: 476) considers this species with *rangiana* and *torulosa*, but there are characters that may entitle it to specific rank. It differs from *torulosa* in the absence of knobs and the pale color of its marsupial expansion. In these characters it resembles *D. p. rangiana*, but it differs from it in the more convex shell, the greatly inflated beaks and the more distinctly developed ridges. In the future more careful study may reveal that *D. sampsoni* is a variant of *perplexa* representing a *rangiana* aspect of it as it appears in the larger rivers.

D. sulcata (Lea). (Call, plate 35).—This is a relatively rare shell in Indiana. It has been taken only from the Ohio, Wabash, White and Maumee rivers. Its characteristic round form with fine green rays on a yellowish background separates it readily from the other species of *Dysnomia* recorded from Indiana.

D. triquetra (Rafinesque). (Call, plate 32).—This is the most common species of the genus in Indiana. It is characterized chiefly by its wide and abruptly truncated posterior slope, its light green color with rays that appear across the ground color in the form of blotches and spots. There is a tendency to confuse this species with *Truncilla truncata*. Usually *D. triquetra* is considerably wider in proportion to the height of the shell than *T. truncata*. Also there is a marked difference in the texture and color of the epidermis of the two species, and *D. triquetra* has a much wider posterior slope which is covered

with fine "dentations," a character not found in *T. truncata*. In Indiana, *D. triquetra* is found in the Wabash, White, St. Joseph and Maumee drainages. It is seldom in large numbers and is associated usually with medium to large river conditions.

Genus *LAMPSILIS* Rafinesque, 1820

Lampsilis anodontoides (Lea). (Call, plate 18).—The common name "Yellow sand-shell" is quite descriptive of this handsome species. It is an important shell industrially, being especially desirable for the manufacture of novelties. Tons of shell of this species were formerly sent to Europe to be used for this purpose. In Indiana it is restricted to streams flowing southward to the Ohio. It has not been taken in the Maumee, St. Joseph or Kankakee drainages of the northern portion of the state. It is mainly a species inhabiting streams of medium to large size. In 1914 C. T. Simpson named a form *fallaciosa* which is smaller than the typical *L. anodontoides* and tends to be marked with prominent green rays, while typical *anodontoides* is usually a bright yellow without any rays. In Indiana *fallaciosa* is relatively rare although a few records of it have been established in the Wabash River drainage. The form seems to be more common in headwaters.

L. fasciola Rafinesque. (Call, plate 37).—This is one of the smaller species of the genus found in Indiana. It is characterized by having a general shape similar to *L. ventricosa*, but it is always smaller at a given age. A series of fine, wavy, green rays are peculiar to the species. Its distribution is of interest in that it does not occur in northwestern Indiana (neither in the St. Joseph nor in the Kankakee). It does occur in the Maumee and most of the streams that drain southward into the Ohio. As a rule, it inhabits small rivers and it is a relatively rare species under large river conditions. If found in lakes it inhabits only those with a strong river influence, i.e., lakes usually classified as "river-lakes."

L. orbiculata (Hildreth). (Call, plate 50).—This species is decidedly limited in its habitat to large rivers. In Indiana there are records from the Ohio, the Wabash and the lower White rivers. There is a superficial resemblance between this species and *Actinonaias carinata*, but the heavy shell, more rounded shape, brown color with indistinct rays, and the tendency to have a delicate pink nacre, are all characters that will help to separate the former from the latter.

L. ovata (Say).—This species is found in Indiana only in the large rivers of the southern part of the state. It has been reported from the Ohio, the Wabash and the lower White rivers. As one progresses into the headwaters the sharp posterior ridge of the true *ovata* is seen to round off and we pass gradually to the more common form of the species in Indiana, known as *L. ovata ventricosa* (Barnes) (See Call, plate 39). *L. ovata* is definitely a species that inhabits larger rivers and there are transitions into the headwaters that connect *L. ovata* through the form *L. o. ventricosa* with *L. ventricosa*.

L. siliquioidea (Barnes). (Call, plate 36).—This species is one of the most common in Indiana. It occupies a wide range of habitats and appears in prac-

tically all of the lakes and streams. It may be separated from *L. ventricosa* largely by its more rectangular shape (*L. ventricosa* is more nearly a square in outline), by its beak sculpture which consists of many fine wavy bars (in *L. ventricosa* there are a few, heavy, concentric bars), and by the less inflated beaks (in *L. ventricosa* the beaks tend to extend considerably above the hinge line). When *siliquioidea* occurs in lakes it may be stunted, and to the depauperate forms the name *L. siliquioidea rosacea* is applied (see Brown, Clark and Gleissner, 1938: 695-98).

L. ventricosa (Barnes). (Call, plate 38).—In Indiana the typical *L. ventricosa* inhabits practically all of the rivers, going well into headwaters. Commonly it is referred to as the "Pocketbook" and is considered (along the the "Mucket") to be one of the best shells for the manufacture of pearl buttons. Occasionally in lakes with a stream influence an ecological form appears which is characterized by a greater or less degree of stunting. Such stunted forms are usually referred to as *L. ventricosa canadensis*. The stunting is due to "exposure" and has been accounted for in an interesting paper by Brown, Clark and Gleissner (1938).

Genus LEPTODEA Rafinesque, 1820

Leptodea blatchleyi (Daniels). (Figured: Plate III, Blatchley and Daniels, 1903).—This rare species has been found only at the type locality: Wabash River, Grand Chains, in Posey County. The species was originally described by L. E. Daniels in the Nautilus (1902) where reference is made to the close similarity in both anatomy and shell characters to *L. leptodon*. More study is necessary to determine the relationship of *blatchleyi* to *leptodon*, which occurs with it.

L. fragilis (Rafinesque).—This species is listed by Call (1900: 464) as *Unio gracilis* and is one of the few he has not figured. It is a common shell in Indiana, but is confined largely to the Wabash and White drainages, i.e., streams that drain southward toward the Ohio River. In northern Indiana it has crossed over into the Maumee drainage and into Lake Erie (Brown, Clark and Gleissner, 1938: 692-93). The species is identified by its well developed posterior wing, its yellow or gray ground color crossed by prominent green rays, its thin shell with thin lamellar teeth. Older specimens tend to lose the winged appearance. This species is most readily confused with *L. laevis*. Characters for separation will be given under that species.

L. laevis (Lea).—This is a relatively rare species in Indiana and is found only in the Ohio and lower Wabash rivers. It is a very fragile shell, and is even thinner than *L. fragilis* which it resembles most closely. *L. laevis* can be separated from *L. fragilis* by the polished appearance of the epidermis, its darker green epidermal cast, and the much thinner and more lamellar hinge teeth.

L. leptodon (Rafinesque).—In Indiana this is one of the rarest of the *Leptodea*. It is found only in the Ohio and lower Wabash rivers. It differs from the *L. fragilis* and *L. laevis* largely by its lack of a prominent wing, although in texture the epidermis is very similar to that of *L. fragilis*. The very rounded ventral margin, lack of a dorsal wing, and the stunted hinge

teeth will aid in separating *leptodon* from *fragilis*. It differs from *L. blatchleyi* largely in size, and *blatchleyi* may be only a form of *leptodon*.

Genus LIGUMIA Swainson, 1840

Ligumia recta latissima (Rafinesque). (Call, plate 17).—In Indiana this species is found in all of the major drainage systems in the state. It is generally associated with larger rivers although occasionally specimens are found in small streams. It is not common to lakes though it does inhabit Lake Erie, which is virtually a huge "river-lake." The type was a stunted form from Lake Erie and consequently the larger, dark colored specimens common to rivers are generally referred to as *L. r. latissima*—a procedure which reverses the usual method of naming the lake forms. Brown, Clark and Gleissner (1938: 694-95) have given valuable information regarding the variation of this species in Lake Erie.

L. subrostrata (Say). (Call, plate 22).—This very characteristic species inhabits both rivers and lakes. In Indiana it seems to be confined to streams belonging to the Wabash and White drainages, and it does not seem to have gotten into drainages of the northern part of the state. It is distinctly a western species and the Indiana records mark the northeastern end of its range. In Lake Erie and on into New England it is replaced by *L. nasuta*, a closely related, but distinctly different species. In ponds and lakes *L. subrostrata* may assume a form known as *furva* which has a high posterior ridge accentuated by a depressed or grooved posterior slope.

Genus MICROMYIA Simpson, 1914

Micromya fabalis (Lea). (Call, plate 23, figs. 1-4).—This small and unusually thick-shelled naiad is among the smallest species found in Indiana. It probably occurs in all of the drainage basins of the state. Records for it are scarce, which may be due to both its small size and to its habitat preference. *M. fabalis* is most common in small streams where it lives buried deep in the sand and gravel around the roots of aquatic vegetation. It is also found in lakes, but usually only those with a definite stream influence.

M. iris (Lea). (Call, plate 21).—In contrast to *M. fabalis* this species is larger and has a decidedly thinner shell and thinner, more lamellar hinge teeth. In distribution and ecology it is similar to *M. fabalis* although in its wide range throughout most of the smaller streams in the state it is far more common than *M. fabalis*.

M. lienosa (Conrad).—In Indiana this species has been reported also under another name, *M. nigerrimus*. It inhabits mainly small and medium sized rivers and has hitherto been found only in the Wabash, the White, and some of the smaller streams draining into the Ohio River. It is not found in the rivers of the northern part of the state. The species is mainly southern in distribution, and southern Indiana marks the northern limit of its range. It differs decidedly in appearance from the two other species of *Micromya* reported here and bears some resemblance to *Ligumia subrostrata*. It is a smaller species, and often the nacre is tinged with purple. It is reported, but not figured, by Blatchley and Daniels (1903: 624-25).

Genus OBLIQUARIA Rafinesque, 1820

Obliquaria reflexa Rafinesque. (Call, plate 27).—The prominent, alternating tubercles on the thickened valves of this species readily separate it from other Indiana shells. This species mainly inhabits larger rivers and is usually not found in great numbers. Its range in Indiana appears to be mainly in the larger rivers such as the Ohio, the Wabash and the White rivers. It has crossed from the Wabash into the Maumee River drainage and has found its way into Lake Erie. Records for its occurrence in the Kankakee and the St. Joseph rivers, as well as for streams in western Michigan, are lacking.

Genus OBOVARIA Rafinesque, 1819

Obovaria olivaria (Rafinesque). (Call, plate 53).—In Indiana, as elsewhere in its range, this species is clearly an inhabitant of large rivers. There are numerous records of its occurrence in the Ohio, the Wabash and the White. In northern Indiana it is a rare shell in the Maumee, the Kankakee and the St. Joseph rivers. *O. olivaria* may be confused with the "Niggerhead" (*Fusconia ebenus*) from which it differs in its "olive" color (*F. ebenus* is black) and its elliptical shape (*F. ebenus* is round, with beaks that arch far forward).

O. retusa (Lamarck). (Call, plate 52).—Like most of the genus in Indiana, this species is mainly found in the large rivers. In the Wabash it ranges from the mouth of the river up to Lafayette. It also occurs in the Ohio and lower portion of the White River drainage. The species has a characteristic purple nacre and its high form, with beaks that arch rather far forward, help to separate it from the other two species of the genus that may occur with it. It is the rarest of the three species of *Obovaria* in Indiana.

O. subrotunda (Rafinesque). (Call, plate 51).—As implied in the specific name, the rounded shape, the almost centrally placed umbones, and the light color of the posterior slope will aid in identifying this species. It is mainly a species of the larger rivers, but it does go into headwaters. The small compressed hearwater form is often referred to as *O. s. lens*. In Indiana, *subrotunda* is most common in streams flowing to the Ohio River, such as the Wabash and White rivers; it has crossed over from the Wabash into the Maumee River, where it is a comparatively rare shell. Records from the Kankakee and the St. Joseph are not well established.

Genus PLAGIOLA Rafinesque, 1819

Plagiola lineolata (Rafinesque). (Call, plate 30).—Among the clammers this pretty shell is known by the name of "Butterfly" since the shell in outline and with its light brown shell crossed by linear dark blotched rays, resembles somewhat the wings of a butterfly. This species is confined largely to the Ohio, White and Wabash rivers where it has a large-river habitat. It has crossed the Wabash-Maumee divide, but is rare in the Maumee River. It is not found in northwestern Indiana.

Genus PROPTERA Rafinesque, 1819

Proptera alata (Say). (Call, plate 25).—As implied in the name this species is characterized by a prominent dorsal wing. It superficially resembles *Leptodea fragilis*, but is a heavier shell, has a darker and less conspicuously rayed epidermis; has a decidedly dark purple nacre (*L. fragilis* has a pink nacre), and has much heavier and more stunted hinge teeth. In Indiana it is mainly a species of the larger rivers, being particularly common in the Ohio, lower White and lower Wabash drainages. It is found in the streams (Maumee, Kankakee and St. Joseph) of northern Indiana, but is a relatively rare shell in that part of the state. Brown, Clark and Gleissner (1938: 691-92) have shown how this species varies in relation to exposure.

P. capax (Green). (Call, plate 40).—This is a rare species in Indiana and has hitherto been found only in the Ohio and lower Wabash (Posey County) rivers. It has a rather peculiar appearance and somewhat resembles an unusually globose *Lampsilis ventricosa*. However, the shiny appearance of the epidermis, the lack of a prominent posterior ridge, and the characteristic tooth structure of the hinge readily identify this species.

Genus PTYCHOBANCHUS Simpson, 1900

Ptychobanchus fasciolaris (Rafinesque). (Call, plate 19).—The hump-backed outline of the shell, its yellow to brown epidermis with broad green rays, the swollen hinge teeth, and a nacre that is always white; all are characters which will help to identify this species. It is mainly found in small streams, and is relatively rare in large rivers. In Indiana it is found in practically all of the drainage basins except those in the northwestern portion of the state, i.e., the Kankakee and the St. Joseph. Apparently this species has gone northward by the Wabash-Maumee route, entering Lake Erie and the streams tributary to that lake. Brown, Clark and Gleissner (1938: 690-91) discuss the variation of this species in Lake Erie. In Indiana *P. fasciolaris* is found usually only in river-lakes.

Genus TRUNCILLA Rafinesque, 1819

Truncilla donaciformis (Lea). (Call, plate 23, figs. 5-7).—This relatively rare species has been recorded from most of the rivers of Indiana. It is somewhat more common in the Ohio, Wabash and White rivers, but there are records of it for the Maumee and St. Joseph as well. Some of the most handsome and largest specimens have been taken from the Wabash River. As a rule, *T. donaciformis* is small, does not have the high sharp posterior ridge common to *T. truncata*, and is marked with characteristic chevron-shaped rays.

T. truncata Rafinesque. (Call, plate 31).—The range of *T. truncata* is very similar to that of *T. donaciformis* and it is not uncommon to find both species in the same habitat. Their appearance together at times occasions difficulty in identification, but usually *T. truncata* can be separated from *donaciformis* by its shape which is compressed, the higher and less obese conformation, and by its darker green color. The markings, like those of *donaciformis*, are zigzag or chevron-shaped rays. Usually *T. truncata* is about twice as large

as *T. donaciformis*. In Indiana huge and handsome specimens appear in the larger rivers of the southern portion of the state. It seems to be less common in the streams of northern Indiana.

DOUBTFUL SPECIES

Dromus dromas (Lea).—The Museum of Zoology, University of Michigan, has one record of this species with unsatisfactory locality data: "White River." It is apparently the only record for *Dromus* in Indiana. It is possible that this species, which occurs in the Ohio River, may have entered the lower White River from that stream. However, until more authentic records are established *Dromus dromas* should be considered as of doubtful occurrence in Indiana.

Family SPHAERIIDAE

The animals of the three genera of this family that occur in Indiana have four gills, the inner ones being the larger ones and parts of these making up the marsupia. The group is hermaphroditic, and the young shells, varying in numbers at any one time, are carried in the parent shell for as much as a year, observation indicates. Nothing definite is known as to the ways of distribution, but since the mollusks are small and light, live in muddy or sandy shallows, and make their appearance in isolated lakes, ponds or even temporary woods and field pools, it is considered that birds play a part in the dispersal. The shells are thin. Lines and ridges on the outer surface show the steps in shell secretion. The inner surface is smooth, and sometimes highly colored, and though this surface is spoken of as nacreous the material does not correspond to the nacre of the Unionidae. The hinge teeth in general consist of more or less well pronounced cardinals and laterals, double in one valve and single in the other. The position of the nepionic valves varies, being centrally placed, a little to one side of the center or in instances close to the terminal margins. In America, only two persons have made thorough taxonomic studies of the Sphaeriidae, Mr. Temple Prime and Dr. Victor Sterki. Upon the latter, dependence for identifications was placed for at least two decades. He named many species and subspecies, but followed no well-defined system of differentiation which could be useful to others. His work has not yet been reviewed and his findings verified. Moore and Butler mentioned only one species in their list of mollusks of Franklin County, Pleas five in Henry County. Ten are in Call's compilation. Showing the Sterki influence, Blatchley and Daniels increased the number by twenty-one and there are thirty-three in Daniels' first catalogue. It has been possible to find about seventy names of species which are accredited to Indiana. Even if faith were sufficiently strong as to believe in the existence of all these forms, descriptions of all of them would be impracticable because of confusing repetitiousness. The course that is followed here is to provide brief definitions of a few well-characterized species under each genus, and mention the others simply by name.

Genus SPHAERIUM Scopoli, 1777

Shell thick as compared with that of the other genera of the family, outer surface of the valves smooth to strongly striate. No sulcus, such as in *Mus-*

culium, causes the umbones to stand apart from subsequent growth. Two cardinals in the left valve, one in the right; laterals in pairs in the right valve, single in the left. The positions of these teeth are occasionally reversed.

Sphaerium sulcatum (Lamarck).—This is the largest member of the genus in America. It is usually inflated, but sometimes compressed. The shape alters in adolescence from oblong to ovate, this being brought about by an increase of secretion of shell material in the center without proportional increase at anterior and posterior margins. Color usually dark, the surface often silken. The striae are crowded, regular. Call speaks of the species as only to be found in the northern part of the state. It is most common in that section, but it has been collected also in Henry and Posey counties.

S. striatinum (Lamarck).—Elongate-ovate, about two-thirds the size of *S. sulcatum*. Striae of varying intensity, the stronger ridges beginning sometimes with post-embryonic growth, sometimes deferred into adolescence. The species is the characteristic one of a very large group possibly not differing specifically, but blessed generously with names. It occurs throughout the state.

S. acuminatum (Prime).—Growth lines very fine, closely set together. Shape very near that of *S. striatinum*. This is the common *Sphaerium* of the Great Lakes. It was found by Daniels in Lake Michigan, Lake and La Porte counties.

S. rhomboideum (Say).—In this species, the juvenile habit of growth is continued into maturity, and is seen to alter only in senile individuals. Commonly inflated, red or brown, rarely nearly colorless. The species appears to flourish best in small, muddy streams, but Call found it in ponds with gravelly bottom, and in lakes of the north. Daniels observed it in Lake Michigan, and in Wawassee Lake, Kosciusko County.

S. occidentale Prime.—Small, orbicular or suborbicular, very thin, surface covered with fine growth lines; color yellow to rose. Apparently a depauperate form. It inhabits ditches, pools and swamps and the marshy areas of lakes, and once in awhile is to be found under wet logs and even in water-filled cow tracks. Not observed by Call, but seen by Pleas in Henry County and by Daniels in La Porte, Kosciusko and Knox counties. It is doubtless in all areas of the state.

The following species have been reported from Indiana or are in collections with Indiana locality labels:

<i>S. solidulum</i> (Prime)	<i>S. emarginatum</i> (Prime)
<i>S. slamineum</i> (Conrad)	<i>S. lacum</i> Sterki
<i>S. vermontanum</i> Chadwick	<i>S. notatum</i> Sterki
<i>S. flavum</i> (Prime)	<i>S. ohioense</i> Sterki
<i>S. fabale</i> (Prime)	<i>S. tenue</i> Prime
<i>S. lineatum</i> Sterki, (type locality: Wawassee Lake.)	

Genus MUSCULIUM Link, 1907

Shell fragile, lines of growth fine, surface usually shining, nepionic shell separated by a septum from the growth which follows it; teeth delicate, tend-

ing toward obsolescence. These small bivalves inhabit pools, muddy shallows of lakes and streams, and occasionally are to be seen in temporary ponds on flood plains.

Musculium transversum (Say).—Oblong, the beaks high and a little anterior to the center of the dorsal edge. Fresh specimens are translucent, and often show the greenish color of the soft parts through the shell. The species is ordinarily in large colonies. It appears to be largely immune to sewage pollution and to flourish in waters having a low free oxygen content. Call remarked abundance in the Ohio and Wabash rivers. It appears to occur rarely in the northern part of the state.

M. partumeium (Say).—Nearly oval, the beaks high; brownish yellow to rose color. It occurs commonly in small colonies, in muddy creeks, woods pools, marshes and bogs of low pH. The Indiana records indicate that the species lives only in the northern part of the state.

M. securis (Prime).—Small, thin and fragile, yellow; orbicular. Shells very much of the same shape, texture and character of beaks have variously been identified as *M. truncatum* (Linsley), *M. rosaceum* (Prime), and *M. securis*. The species was not distinguished by Call from *M. partumeium*. Daniels found it in Kosciusko County, but it is probably in all other sections of the state.

The following Indiana mollusks in the Daniels collection were identified by Sterki under these names:

M. orbiculare Sterki
M. sphaericum (Anthony)
M. jayanum Prime

M. securis parvum Sterki
M. truncatum albidum Sterki
M. lacustre Müller

Genus PISIDIUM C. Pfeiffer, 1821

Members of this genus are small, some of them minute. The shape varies from suborbicular to trapezoidal. Beaks may be high or on a plane with the hinge line, or nearly so. The teeth vary somewhat in development and form, and some attempt has been made in Europe to set up specific differentiations upon this character. The foot relative to the size of the shell is larger than in *Sphaerium*, and in detail the siphons are different. In descriptions, stress has been laid on small variations in shell shape although in the same species this may be different at different stages of growth. The habitats are mud or sand or among aquatic plants. Some of these mollusks have been dredged from lake depths where free oxygen is scant or altogether absent, and as in the case of other organisms in such situations this has given rise to several speculations as to how the oxygen necessary for metabolism is supplied, none of them wholly satisfactory.

Pisidium compressum Prime.—Trigonal, the beaks high and rather strongly indicated; surface smooth, showing lines of growth and sometimes interruptions of growth which may be seasonal. Length seldom reaching four millimeters. Cardinal teeth strong for so small a mollusk. Daniels found it in

northern lakes of the state, but it appears to live more often in muddy shallows of streams.

P. abditum Haldeman.—Less wedge-shaped than *P. compressum* and with low beaks. A full-grown specimen from Indiana measured 3.46 mm. in length, 3.10 mm. in height and 2.10 mm. in diameter. The species was collected by Pleas in Henry County, by Call in the Ohio and Wabash rivers and the canal at Brookville and "numerous small streams over the state." It is in the Daniels collection from Lake County.

P. virginicum (Gmelin).—Large for the genus, its length sometimes seven millimeters. Bears are close to the posterior end, and give the shell a rather striking obliquity. The cardinal tooth in the right valve is triangular, stout. Call found the shell only in the Maumee River at Fort Wayne. Daniels reported it from the Kankakee River, Starke County, and his collection contains specimens from Lake Maxinkuckee and Lost Lake, Marshall County; Bass Lake, Starke County, Lake James, Steuben County, and Lake Michigan, Lake County.

P. idahoense indianense Sterki.—As large as *P. virginicum*, but ovate or subovate, the shell thick for the genus, the beaks elevated. Known from Lake Michigan, Lake County.

These species or subspecies have been listed as from Indiana or are in collections with Indiana locality data:

P. compressum laevigatum Sterki

P. compressum rostratum Sterki

P. punctatum Sterki

P. variabile Prime

P. glabellum Sterki

P. adamsi Prime

P. adamsi affine Sterki

P. sargenti Sterki

P. noveboracense Prime

P. scutellatum Sterki

P. mainense Sterki

P. milium Held

P. roperi Sterki

P. strengi Sterki

P. politum Sterki

P. politum decorum Sterki

P. subrotundum Sterki

P. danielsi Sterki, type locality: spring near Lake James, Steuben County.

P. hinckleyi Sterki, type locality: Wabash River, Grand Chains, Posey County.

P. vesiculare striatellum Sterki, type

locality: Lake Maxinkuckee, Marshall County.

P. medianum clarum Sterki, type locality: Clear Lake, Steuben County.

P. splendidulum Sterki

P. tenuissimum Sterki

P. pauperculum Sterki

P. pauperculum crystalense Sterki

P. rotundatum Sterki

P. peraltum Sterki

P. vesiculare Sterki

P. medianum Sterki

P. obtusale C. Pfeiffer

P. kirilandi Sterki

P. ambiguum Sterki

P. concinnulum Sterki

P. nanum Sterki

P. parallelum Sterki

P. pusillum Gmelin, Jenyns

P. streatori Sterki

P. trapezoideum Sterki

P. walkei Sterki

REFERENCES

- ALLEN, W. R. 1914—The Food and Feeding Habits of Freshwater Mussels. Biol. Bull. 27:127-139.
—1921—Studies of the Biology of Freshwater Mussels. Two papers: I. Experimental Studies of the Food Relations of Certain Unionidae. Biol. Bull. 40:

- 210-241; III. Distribution and Movements of Winona Lake Mussels. *Proc. Indiana Acad. Sci.*: 227-238.
- 1923—Studies of the Biology of Freshwater Mussels. II. The Nature and Degree of Response to Certain Physical and Chemical Stimuli. *Ohio Jour. Sci.* **23**(2): 57-82.
- BAKER, F. C. 1898—The Mollusca of the Chicago Area. Part I. *Chicago Acad. Sci. Bull.* **3**:1-130.
- 1902—*Ibid.*, Part 2: 131-420, Pls. 1-36.
- 1904—The Mollusks of Cedar Lake, Indiana. *Nautilus* **17**:112-113.
- 1905—Notes on a Collection of Shells from Bass Lake, Indiana. *Nautilus* **19**:27-28.
- 1906—*Lymnaea danielsi* Sp. Nov. *Nautilus* **20**:55-56.
- 1907—Descriptions of New Series of *Lymnaea*. *Nautilus* **20**:125-127.
- 1911—The *Lymnaeidae* of North and Middle America. *Chicago Acad. Sci. Spec. Pub.* **3**, i-xvi., 1-539, Pls. 1-58.
- 1935—Mollusca from Turkey Run State Park, Indiana. *Nautilus* **48**:105-06.
- 1939—Fieldbook of Illinois Land Snails. Urbana. Pp. 1-166.
- BILLUPS, A. C. 1902—Fossil Land Shells of the old Forest Bed of the Ohio River. *Nautilus* **16**:50-52.
- 1902—*Angitrema verrucosa* at Lawrenceburg, Indiana. *Nautilus* **16**:72.
- 1903—Adaptation of Mollusks to Changed Conditions. *Nautilus* **16**:112-114.
- BLATCHLEY, W. S. 1901—A List of the Mollusca Known to Occur in Lake Maxinkuckee. 25th. Ann. Report Indiana Dept. Geol. & Nat. Resources. Indianapolis, Pp. 577-680, Pls. 1-3, Figs. 1-42.
- BLATCHLEY, W. S. AND L. E. DANIELS. 1903—On Some Mollusca Known to Occur in Indiana. 26th. Ann. Report Indiana Geol. Survey, Pp. 577-628.
- BROWN, C. J. D., C. CLARK AND B. GLEISSNER. 1938—The Size of Certain Naiades from Western Lake Erie in Relation to Shoal Exposure. *Amer. Midland Nat.* **19**:682-701.
- CAHN, A. R. AND JACK T. KEMP. 1929—The Terrestrial Mollusca of Turkey Run State Park, Indiana. *Nautilus* **43**:66-68.
- CALL, R. E. 1885—Geographic Distribution of the *Unionidae* of the Mississippi Valley. *Bull. Des Moines Acad. Sci.* **1**:5-56.
- 1894—A Contribution to the Knowledge of Indiana Mollusca. *Proc. Indiana Acad. Sci.*: 140-156.
- 1894—Geographic and Hypsometric Distribution of North American Viviparidae. *Proc. Indiana Acad. Sci.*: 225-226.
- 1894—A Revision and Synonymy of the Parvus Group of *Unionidae*. *Proc. Indiana Acad. Sci.*: 109-119, Pls. 1-6.
- 1895—*Unionidae* of the Ohio River. *Proc. Indiana Acad. Sci.* 139-140.
- 1895—The *Strepomatidae* of the Falls of the Ohio. *Proc. Indiana Acad. Sci.* 140-143.
- 1895—On a Small Collection of Mollusks from Northern Indiana. *Proc. Ind. Acad. Sci.* 246-250.
- 1896—Second Contribution to a Knowledge of Indiana Mollusca. *Proc. Ind. Acad. Sci.* 135-146.
- 1896—The Hydrographic Basins of Indiana and their Molluscan Fauna. *Proc. Indiana Acad. Sci.* 247-258.
- 1900—A Descriptive Illustrated Catalogue of the Mollusca of Indiana. 24th. Ann. Report Geol. Survey Indiana. Indianapolis. Pp. 335-535, Pls. 1-76.
- DANIELS, L. E. 1902—A New Species of *Lampsilis*. *Nautilus* **16**:13-14.
- 1903—A Check List of Indiana Mollusca, with Localities. 26th. Ann. Report Indiana Dept. Geol. & Natural Resources. Indianapolis. Pp. 629-652.

- 1904—Geographic Range of *Polygyra Tridentata Discoidea*. *Nautilus* 18:32.
- 1905—Notes on the Semi-Fossil Shells of Posey County, Indiana. *Nautilus* 19:62-63.
- 1914—A Supplemental Check List of Indiana Mollusca with Localities and Notes. 39th Ann. Report Indiana Dept. Geol. & Natural Resources, Indianapolis. Pp. 318-326.
- EVERMANN, B. W. AND H. W. CLARK. 1918—The Unionidae of Lake Maxinkuckee. *Proc. Indiana Acad. Sci.* 251-285.
- 1920—Lake Maxinkuckee, a Physical and Biological Survey. Indianapolis. 2:41-75.
- FERRISS, J. H. 1919—Lorenzo E. Daniels. *Nautilus* 32:99-101.
- GOODRICH, C. 1914—Union of the Wabash and Maumee Drainage Systems. *Nautilus* 27:131-132.
- 1921—River Barriers to Aquatic Animals. *Nautilus* 35:1-4.
- 1924—Some Old Pleuroceridae and a New One. *Nautilus* 38:43-48.
- 1929—The Pleurocerid Fauna of the Falls of the Ohio. *Nautilus* 43:1-17.
- 1942—The American Species of *Viviparus*. *Nautilus* 55:82-92.
- HEADLEE, T. J. 1908—Ecological Notes on the Mussels of Winona, Pike and Center Lakes of Kosciusko Co., Indiana. *Biol. Bull.* 11(6):305-318, Pls. 12, Figs. 1-2.
- HEADLEE, T. J. AND JAMES SIMONTON. 1904—Ecological Notes on the Mussels of Winona Lake. *Proc. Indiana Acad. Sci.* 173-178, Pls. 1-2.
- HENDERSON, J. 1919—Some Further Comments Upon the Work of Lorenzo Eugene Daniels. *Nautilus* 32:137-138.
- HICKMAN, C. P. 1927—Formation of the Intranuclear Rod in *Succinea Ovalis* Say. *Proc. Indiana Acad. Sci.* 36:317-318.
- HIESTAND, W. A. 1938—Respiration Studies with Fresh-Water Molluscs I. Oxygen Consumption in Relation to Oxygen Tension; II. Oxygen Consumption in Relation to Hydrogen-Ion Concentration. *Proc. Indiana Acad. Sci.* 47:287-292, 293-298.
- HINKLEY, A. A. 1888—Notes on the Strepomatidae of Illinois. *Conchologists' Exchange* 2:93-94.
- 1908—A New Species of *Pyrgulopsis*. *Nautilus* 21:117-118.
- 1908—*Meschiza Grosvernorii* Lea. *Nautilus* 22:56.
- JONES, D. T. 1923—Some Anatomical Features of the Tiger Snail, *Anguispira Alternata* (Say). *Proc. Indiana Acad. Sci.* 42:243-250, 2 plates.
- LYON, M. W., JR. 1923—*Goniobasis Livescens* Menke, a Pleistocene Shell in Furnessville Blowout, Dunes of Porter County. *Proc. Indiana Acad. Sci.* 123-124.
- McMURTRIE, H. 1819—Sketches of Louisville and its Environs. Louisville. P. 66.
- MOORE, D. R. AND A. W. BUTLER. 1885—Land and Fresh Water Mollusca Observed in Franklin County, Indiana. *Bull. Brookville Soc. Nat. Hist.* 1:41-44.
- NORRIS, A. A. 1902—A List of the Mollusca of Eagle, Center and Pike Lakes, Kosciusko County, Indiana. *Proc. Indiana Acad. Sci.* 118-119.
- ORTMANN, A. E. 1915—Studies in *Najades*. *Nautilus* 28:106-108.
- ORTMANN, A. E. AND B. WALKER. 1922—On the Nomenclature of Certain North American *Naiades*. *Occ. Papers Mus. Zool., Univ. Mich.* No. 112: 1-75.
- PILSBRY, H. A. 1903—Descriptions of two species in Blatchley and Daniels, On Some Mollusca Known to Occur in Indiana. 26th Ann. Report Indiana Geol. Survey. Pp. 604, 605.
- 1904—A New Subspecies of *Polygyra Tridentata* subsp. *discoidea*. *Nautilus* 17:142.
- 1905—A New Species of *Succinea*. *Nautilus* 19:28-29.
- 1917—*Rafinesque's* Genera of Freshwater Snails. *Nautilus* 30:109-114.

- 1935—*Lioplax Subcarinata Occidentalis*. *Nautilus* **48**:143-144.
- PLEAS, E. 1893—Shells of Henry Co., Indiana. *Nautilus* **7**:68-70.
- PLUMMER, J. T. 1844—Scraps of Natural History (Mollusca). *Amer. Jour. Sci. & Arts* **48**:93-96.
- RAFINESQUE, C. S. 1820—Monograph des Conquilles bivalves et fluviatiles de Rivière Ohio. *Ann. Gen. Sci. Phys. Bruxelles* **5**:287-322.
- 1864—The Complete Writings on Recent and Fossil Conchology. Edited by Binney and Tryon. Pp. 1-103, Pls. 1-3.
- SAY, T. 1858—The Complete Writings of Thomas Say. New York. Pp. 1-252, with 75 unnumbered plates.
- SCOTT, W. 1925—The Biota of the Upper Tippecanoe River. *Proc. Indiana Acad. Sci.* **35**:365-367.
- SCOTT, W., RALPH O. HILE AND HERMAN T. SPIETH. 1928—A Quantitative Study of the Bottom Fauna of Lake Wauwassee (Turkey Lake). *Pub. 77 Dept. Conservation Indiana* 1-25.
- SIMPSON, C. T. 1900—Unionidae of Indiana. *Nautilus* **14**:95-96.
- STEIN, F. 1881—Report on the Molluscan Fauna of Indiana. *Ann. Report Geol. Survey Indiana for the Year 1880*. Indianapolis. Pp. 451-467.
- STERKI, V. 1905—New Varieties of North American Pisidia. *Nautilus* **19**:80-84.
- 1910—New Species of Sphaeriidae. *Nautilus* **23**:142-143.
- THOMPSON, C. O. 1926—Some Habits of *Limax Maximus*. *Proc. Indiana Acad. Sci.* **36**:309-310.
- TUCKER, M. E. 1928—Studies of the Life Cycles of Two Species of Fresh-Water Mussels Belonging to the Genus *Anodonta*. *Biol. Bull. Marine Biol. Labor.* **54**:117-127.
- VAN DER SCHALIE, H. 1936—The Naiad Fauna of the St. Joseph River Drainage in Southwestern Michigan. *Amer. Midland Nat.* **17**:523-527.
- 1939—Additional Notes on the Naiades (Fresh-Water Mussels) of the Lower Tennessee River. *Amer. Midland Nat.* **22**:452-457.
- 1940—Aestivation of Fresh-Water Mussels. *Nautilus* **53**:137-138.
- 1941—The Taxonomy of Naiades Inhabiting a Lake Environment. *Jour. Conchol.* **21**:246-253.
- WALKER, B. 1908—On Certain Immature Anculosae. *Nautilus* **21**:110-117.
- 1920—A New Fresh-Water Mollusk from Indiana. *Proc. U. S. Nat. Mus.* **57**:525.
- WEBB, G. R. 1942—*Mesodon Appressus* (Say) in Marion County, Indiana. *Nautilus* **56**:61-62.
- WENNINGER, F. 1921—A Preliminary Report on the Unionidae of the St. Joseph River. *Amer. Midland Nat.* **7**:1-28.
- WHITNEY, M. E. 1938—Some Observations on the Reproductive Cycle of a Common Land Snail, *Vallonia Pulchella*. Influence of Environmental Factors. *Proc. Indiana Acad. Sci.* **47**:299-307.
- WILSON, C. B. AND H. W. CLARK. 1912—The Mussel Fauna of the Maumee River. *U. S. Bureau Fish. Doc.* **757**:1-72, Pls. 1-2.
- 1912—The Mussel Fauna of the Kankakee River. *Ibid.*, *Doc.* 758:1-52.
- WRIGHT, H. P. 1932—Aquatic Mollusca of the Tippecanoe River System, Part I. Post Glacial Migration and Present Distribution of four Species of Snails. *Ecological Monographs* **2**:233-259.
- 1932—The Physiography of the Tippecanoe River. *Proc. Indiana Acad. Sci.* **41**:495-506.

New American Species of the Ostracod Genus *Entocythere*

C. Clayton Hoff

Through the kindness of Dr. Horton H. Hobbs, Jr., of the University of Florida, the writer was privileged to examine ostracods epizoic on crayfishes collected in the southeastern United States. Material was secured from seventy-six collections distributed as follows: Florida, fifty-three collections; Georgia, sixteen; Alabama, six; and South Carolina, one. In this material, there were found several new species of *Entocythere*, five of which occurred in sufficient numbers to merit study and description at this time. In addition to these five new species, the present paper records the description of a new species from Illinois.

The method used in preparing the material for study were much the same as recorded previously by Hoff (1942). The present specimens, however, were cleared in xylol and mounted in clarite except for a few individuals which were mounted experimentally in hyrax. For mounting *Entocythere*, hyrax was found no better, and indeed inferior, to clarite. Shell measurements are given to the nearest 0.01 mm. All drawings were made with a camera lucida and, unless otherwise indicated, are of specimens mounted in clarite.

Type specimens, including the holotype, allotype, and some paratypes of each species, are deposited in the United States National Museum as indicated under each description. Other paratypes are to be found in the Chicago Museum of Natural History and in the personal collections of Dr. Hobbs and of the writer.

Notes on Some Specific and Generic Characteristics

With discovery during the past few years of a number of new species of *Entocythere* (Rioja, 1940, 1942a, 1942b, 1944; Dobbin, 1941; Hoff, 1942, 1943), several changes relative to the characterization of the genus appear expedient. It is now apparent that certain characteristics previously considered as specific criteria may in the future become a part of the generic diagnosis. This future generic revision, which will be made possible by a thorough restudy of previously described species and the discovery of new species, will tend to establish a more definite and restricted characterization of the genus.

The problems of species diagnoses and intrageneric relationships are often complicated by statements in the literature which appear erroneous but which have not been proven false because of the inability of recent writers to secure material from either the type collection or the type locality. In some instances, the species has never been seen except by the original describer. For instance, *E. donaldsonensis* (Klie 1931) is described as having two end claws on the antenna of the male. This is probably an error on the part of Klie since the median end claw in species of *Entocythere* is often small and easily over-

looked. If two end claws do occur in the males of *E. donnaldsonensis*, the condition is indeed unique since in all other species in which the male is described, three end claws are reported. Another instance of a possible error is the report by Sars (1926) of seven podomeres in the antennule of *E. insignipes*. All other species of Entocythere are reported as having six podomeres in the antennule. Sars could easily have made an erroneous observation since the cephalic wall in many Entocythere species is drawn out into a papillate or cylindrical process upon which the antennule is mounted. Except by very close examination of favorable material, this process easily may be mistaken for a basal podomere.

Some apparent errors in species descriptions have also resulted from the use by various authors of different methods of preparation and study of material. This is particularly true with reference to the mandibular and maxillary palps, in which the podomeres may be fused together in varying degrees. The weak sutures which limit the podomeres may be made more conspicuous by use of certain stains and mounting media. Under these variable conditions, the reported extent of fusion of the podomeres is probably not in every instance a reliable criterion upon which to base species separations.

In some cases, confusion and errors have resulted from a lack of definite names for certain structures used in taxonomic descriptions. This is particularly true of the male copulatory structures, which furnish the most important specific criteria. It would appear that definite separation of species as well as future subdivision of the genus into subgenera must ultimately rest upon the characteristics supplied by the sexual structures, especially the clasping apparatus of the male complex. The more attention received by species of this genus, the more taxonomic and diagnostic importance becomes attached to the male structures since the parts of the male copulatory complex show marked differences among the various species, exhibit definite limits of variability, and are more satisfactorily observed than most other structures. Usage of the number and position of setae of the appendages is very limited in this group as far as specific diagnosis is concerned since there is often little difference among species and the setae are difficult to observe except under the most fortunate conditions. Structures having the most taxonomic significance may be listed in order of decreasing importance as follows: structures of the male copulatory complex, especially the clasping apparatus; the size and shape of the shell; details of the mandible and maxilla; and details of the antenna, especially in those females which possess peculiar scale-like structures on the ultimate podomere (e. g., *E. elliptica* sp. nov., Fig. 21).

The Male Copulatory Complex

In order to make available terminology useful in describing parts of the male copulatory complex, the writer has either described and assigned names to various structures which formerly were nameless or has retained previously used names when such are available. Rioja is to be given credit for many of the terms used in connection with the parts of the male copulatory complex.

The copulatory apparatus or complex is paired, each of the pair consisting

of a plate-like base which is connected to the body by the *connecting piece* (Fig. 31, CP). The base itself is divided into two parts which are called the *proximal portion of the base* (Fig. 31, PP) and the *distal portion of the base* (Figs. 18, 25, and 31, DP). In most species of Entocythere, the two portions appear fused together. The proximal portion is smaller than the distal, often being about as wide as long, while the distal portion is usually much elongated. The proximal portion lies between the connecting piece and the distal portion and forms the attachment place for three projections or processes, of which the proximal or dorsalmost two are weakly chitinous. Of these two, the dorsal one is short, often fleshy in appearance, and bears distally a simple or sometimes bifurcated spine. It is suggested that this process be called the *dorsal finger* (Figs. 25, 31, DF). The second, more ventrally attached projection is much longer, bar-shaped, and of uniform width throughout. It bears distally a spine roughly equal in length to the spine of the dorsal finger. This second process or projection is designated as the *ventral finger* (Figs. 25, 31, VF). "Fingers" appear as appropriate names for these projections since they are probably tactile in nature and may also assist in directing or holding certain structures in position during copulation. Previously it was asserted but not proven (Marshall, 1903) that one of these two fingers, possibly the ventral one, contained the sperm duct. That no duct is present in either of the two fingers is shown by careful examination under a magnification of 1400 times and by the fact that the sperm duct may be traced, not to one of the fingers, but to an apparent penis (Fig. 31, P) located in the distal portion of the base.

The ventralmost projection or process of the proximal portion of the base is the *clasping apparatus* (Marshall, 1903; Rioja, 1940) (Fig. 25, EB; Fig. 31, HR). This strongly chitinous, variously shaped structure displays the most valuable of all diagnostic characteristics useful in this group. The function of the clasping apparatus apparently is to contact and hold the female organs during copulation, thus bringing the male and female pores into juxtaposition. In most instances, the clasping apparatus may be divided into a definite *vertical ramus* (Figs. 18, 31, HR) and a *horizontal ramus* (Fig. 18, VR). In some species the two rami are well differentiated, but in other forms the two rami join together without marked interruption. The vertical ramus ordinarily lies along and extends beyond the anterior margin of the distal portion of the base when the organs are in the copulatory position. Since the clasping apparatus is usually L-shaped or C-shaped, an *internal border* (Fig. 25, IB) and an *external border* (Fig. 25, EB) may be recognized, the former being the concave margin and the latter the convex margin. The internal border of the horizontal ramus is commonly marked by teeth, whose size and position are of distinct taxonomic significance. On the external border teeth are less frequent, the border being in many instances entire. In some forms a projection extends from the external border of the horizontal ramus. This projection, from its position and nature, is called the *talon* (claw or heel) (Rioja, 1942a) (Fig. 31, T). The area of the horizontal ramus distal to the origin of the talon is designated as the *post-talon portion* (Fig. 31, PT). Terminally the horizontal ramus usually forms a *distal margin* (Fig. 25, DM) marked by a few fine teeth.

With respect to the penis (Fig. 31, P), examination with the oil immersion objective and a 15x ocular usually shows what appears to be an actual intromittent organ located in the distal portion of the base. The position of this organ may often be determined, if in no other way, by tracing the course of the sperm duct through the base. This penis seems to lie in a hollow cavity or atrium from which it may protrude medially during copulation.

Subgeneric Groups

Among present questions concerning the genus *Entocythere* is the establishment of subgenera. At the time of the description of the subfamily Entocytherinae (Hoff, 1942), the writer divided the genus *Entocythere* into two subgenera, *Entocythere* and *Cytherites*, on the basis of the size of the shell and the number of end claws on the antenna of the female. Rioja (1942b, 1944) elaborating upon the subgeneric categories already established and taking into consideration the recently discovered dimorphism in the antenna of the females, revised the subgenera and added a third, *Donnaldsoncythere*, to include a single species, *E. donnaldsonensis* Klie 1931. This subgenus is characterized by two antennal claws in both the male and the female. This division of the genus into subgenera on the basis of the number of end claws of the antenna appeared at one time a natural classification since, when only a few species were known to belong to the genus, this characteristic was correlated with the shell size and the number of setae in the respiratory plate of the maxilla. Now that additional species have been described and the dimorphism of females seems possibly to be universal in the genus, it appears that any division into subgenera on the basis of the number of end claws of the antenna is inadvisable and should be discarded.

While it appears impossible at this time to suggest an adequate system of subdividing the genus *Entocythere*, certain natural intrageneric groups may be suggested. One such group includes *E. illinoisensis* Hoff 1942, *E. claytonhoffi* Rioja 1942, *E. mexicana* Rioja 1944, and *E. elliptica* sp. nov. The group formed of these four species is characterized by the relatively large size of the shell, by the presence of accessory structures on the ultimate podomere of the antenna of the female, and by the stout, L-shaped clasping apparatus. As a result of the shell size and the shape of the clasping apparatus, it is possible that *E. cambaria* Marshall 1903 would also belong to this group (in which case the group would be equal to the subgenus *Entocythere*) but the antenna of the female is not described as having accessory structures on the last podomere. Whether Marshall overlooked these structures or they actually are wanting cannot be decided until individuals belonging to the species are available for study. Another possible natural group might be established on the basis of the presence of a talon on the clasping apparatus of the male. Such a group (group *heterodonta* Rioja 1944) would include a number of species: *E. heterodonta* Rioja 1940, *E. copiosa* Hoff 1942, *E. sinuosa* Rioja 1942, *E. hobbsi* sp. nov., and perhaps in addition *E. talulus* sp. nov. in which the talon is greatly reduced or rudimentary. Other species of *Entocythere*, which do not fall into either of these two groups apparently do not, as a result of great diversity in the structure of the clasping apparatus, fall into natural assem-

blages. To this writer, it appears inadvisable at this time to promote any scheme to subdivide the genus. When descriptions of known species have been closely checked and when most of the possibly existing Entocythere species have been described, then the time will be opportune for a survey of the genus as a whole and the establishment, if possible, of *natural* subgeneric groups.

KEY TO KNOWN SPECIES OF THE GENUS ENTOCYTHERE

(Based entirely upon male characteristics, chiefly those of the clasping apparatus)

- 1a. Antennule¹ composed of seven podomeres and with three distal setae.....*E. insignipes* (Sars 1926) Hoff 1942
- b. Antennule composed of six podomeres and with four or more distal setae..... 2
- 2a. External border of clasping apparatus of male entire..... 3
- b. A talon or teeth present on the external border of the clasping apparatus of the male 16
- 3a. Horizontal ramus very short, reduced to a mere lobe at the end of the vertical ramus 4
- b. Horizontal ramus over one third the length of the vertical 5
- 4a. End of the clasping apparatus fan-shaped, corrugated, with rounded or blunt teeth; male antenna with three distal claws.....*E. humesi* Hoff 1943
- b. End of clasping apparatus with acute teeth, male antenna reported as having only two distal claws.....*E. donaldsonensis* Klie 1931
- 5a. The terminal end of the distal portion of the base of the male copulatory complex forming a long, narrow process extending nearly parallel to the clasping apparatus*E. serrata* sp. nov.
- b. The terminal end of the distal portion of the base not forming such a process..... 6
- 6a. The juncture of the vertical and horizontal rami forms a pronounced angle, the external border being extended to form a pointed projection.....*E. illinoisensis* Hoff 1942
- b. The border at the juncture of the two rami forming nearly a simple right angle or merely rounded 7
- 7a. Shell greatly enlarged anteriorly and ventrally*E. claytonhoffi* Rioja 1942
- b. Shell not so enlarged 8
- 8a. Clasping apparatus stout, swollen at juncture of the two rami; the two rami never joined at an angle much greater than a right angle 9
- b. Clasping apparatus slender, little if any swollen at the juncture of the vertical and the horizontal rami 11
- 9a. Vertical ramus much longer than the horizontal ramus*E. elliptica* sp. nov.
- b. Vertical and horizontal rami approximately equal in length..... 10
- 10a. Vertical ramus proximally wider than in the center of the ramus; both rami relatively slender near the ends of the clasping apparatus.....*E. mexicana* Rioja 1944
- b. Ventral ramus wider in center than at the proximal end; both rami relatively stout throughout*E. cambaria* Marshall 1903
- 11a. Clasping apparatus C-shaped; distal margin with two teeth..... 12

¹ Sars' description of *Entocythere* (*Cytherites*) *insignipes* does not include a description of the male. Since sexual dimorphism as far as known in this group does not extend to the antennules, separation may be made on the number of podomeres of the antennule and the number of distal setae. A question arises, however, as indicated earlier in this paper, with respect to the accuracy of Sars' observations relative to the number of podomeres in the antennule.

- b. Clasp ing apparatus not distinctly C-shaped; distal margin with more than two teeth14
- 12a. Teeth of internal border of horizontal ramus of clasp ing apparatus grouped together some distance from the distal margin; dorsal margin of shell evenly rounded*E. equicurva* sp. nov. 13
- b. Teeth of internal border well spaced; dorsal margin of shell not evenly rounded.....
- 13a. Three teeth on internal border of clasp ing apparatus.....*E. dobbiniae* Rioja 1944
- b. Two teeth on internal border.....*E. d. bicuspis* Rioja 1944
- 14a. Vertical ramus shorter than the horizontal; shell with a posterior projection.....*E. columbia* Dobbin 1941
- b. Vertical ramus not shorter than the horizontal; shell without posterior projection.....15
- 15a. Teeth of internal border of clasp ing apparatus weak; internal border of vertical ramus straight or concave.....*E. riojai* Hoff 1943
- b. Teeth of internal border well developed; internal border of the vertical ramus weakly convex*E. dorsorotunda* sp. nov.
- 16a. Two teeth on external border of horizontal ramus nearly equal in size.....*E. talulus* sp. nov.
- b. External border of horizontal ramus with two teeth of which the proximal tooth is enlarged to form a talon or with only a talon17
- 17a. Talon much longer than width of ramus at base of talon.....18
- b. Talon little if any longer than width of ramus at base of talon.....19
- 18a. Talon long, recurved and extending in its distal part parallel to the post-talon portion of the clasp ing apparatus.....*E. hobbsi* sp. nov.
- b. Talon not so long, little recurved, and not extending parallel to the horizontal ramus*E. copiosa* Hoff 1942
- 19a. Clasp ing apparatus nearly evenly curved throughout.....*E. heterodonta* Rioja 1940
- b. Vertical ramus proximally straightened.....*E. sinuosa* Rioja 1942

Descriptions of New Species

Entocythere serrata sp. nov.

Figs. 1-5

In 1942 the writer had, in addition to the two species described as new (Hoff 1942), another form represented by a single male individual, which had been collected on August 31, 1940, in water pumped from a crayfish burrow in a swamp, spring-fed meadow area on the farm of Mr. Roy Foster, located three miles west of Alpha, Henry County, Illinois. During the summer of 1943, the writer returned to the same area and on June 25 collected from the burrows two crayfish identified by Dr. Horton H. Hobbs, Jr. as *Cambarus diogenes diogenes* Girard. These crayfish carried the ostracods upon which this description is based. Holotype (male), allotype (gravid female), and paratypes (both sexes), U. S. N. M.

Male.—The shell (Fig. 1) of the male is subelliptical in outline, with the anterior end slightly narrower than the posterior. The right valve is a little higher than the left. The dorsal margin forms a somewhat elevated and, except for a slightly flattened anterior slope, a fairly even arc continuous with the anterior and posterior margins. The ventral margin is weakly convex to almost straight and passes without interruption into the posterior and anterior margins. Both the anterior and posterior margins are fairly well rounded, except

that above the midpoint, the anterior margin is often marked by a feeble break in the arc while the midpoint of the posterior margin may show not only a break of the marginal arc but, in some individuals, a slight papillate bulge. These breaks in the end margins, however, are in some valves almost wanting. The shell is nearly destitute of setae, there being a very few, not over 12 or 15, short fine hairs evenly spaced along the ventral and end margins of each valve of the shell. On the dorsal part of each valve, conspicuous flecks of dark brown pigment are often grouped into definite patches although sometimes isolated flecks may be scattered on various parts of the dorsal portion of the shell behind the eye. The well developed eye is located not more than one fifth of the shell length from the anterior end. In general, the shell, because of lack of peculiarities, offers few characteristics useful in species diagnosis.

The shell size, especially the length, is fairly constant as shown by shell measurements of the following males (mounted as indicated in either clarite or hyrax and measured to the nearest 0.01 mm.):

Length	Height	
0.48 mm.	0.28 mm.	(holotype, clarite)
0.48	0.25	(paratype, clarite)
0.50	0.30	(paratype, hyrax)
0.48	0.29	(paratype, hyrax)
0.49	0.27	(paratype, clarite)

Each antennule is composed of six podomeres, which, with the exception of the much elongated first or basal podomere and the somewhat shortened third podomere, are equal or subequal in length. The diameter of successive podomeres decreases regularly from proximal to distal. The basal podomere bears one seta, heavy and spine-like, placed subdistally and medio-ventrally and about as long as the second podomere; the second podomere has a distal-medial seta; the third podomere bears one seta on the extensor-distal corner of the podomere and another submedially on the distal margin; the fourth or antepenultimate podomere has six setae arranged around the distal edge of the podomere; the penultimate podomere is destitute of setae; while the ultimate podomere bears five setae, of which one is only about four-fifths as long as each of the others. With the exception of the seta of the basal podomere, all are long and slender.

The antenna offers few characteristics useful in species identification. Each antenna consists of four podomeres, with the penultimate divided into two parts. The second podomere is almost one and one-half times as long as wide, while the two parts of the penultimate are subequal in length. The second podomere bears distally on the flexor side a stout seta which reaches nearly to the level of the proximal surface of the last podomere of the appendage. The distal-flexor corner of the basal portion of the penultimate podomere bears two fairly stout setae, the lateral one of which is much the longer, reaching to the level of the ultimate podomere. The shorter of the two has a length of no more than two-thirds of the first. The distal portion of the penultimate podomere bears a single seta located near the midpoint of the flexor surface. This seta, which is usually bent near the distal end, reaches almost to the level

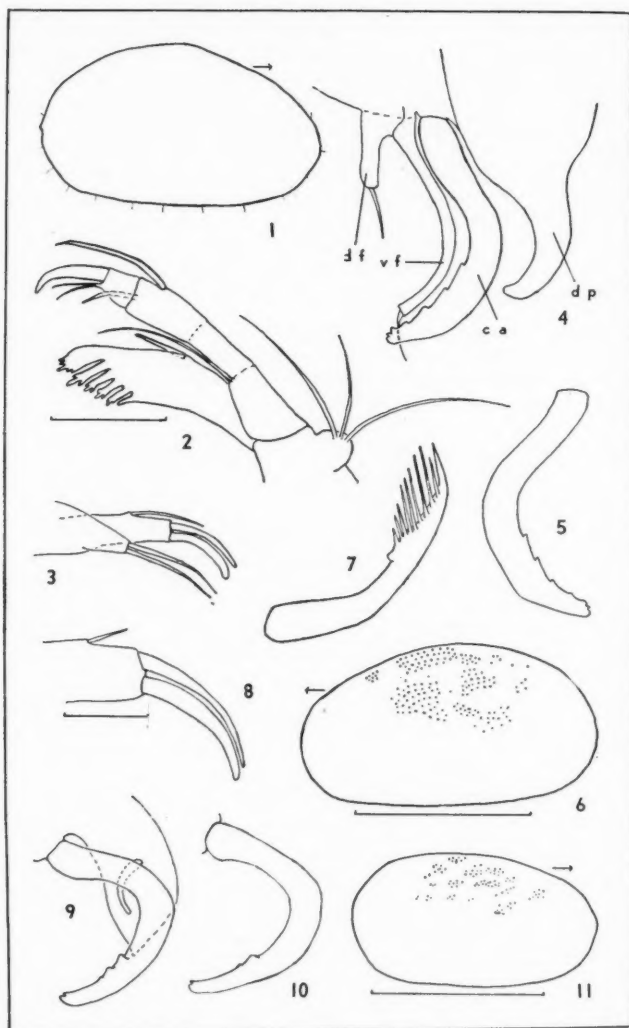


PLATE 1: Figs. 1-5. *Entocythere serrata* sp. nov. 1. Outline of right valve of male holotype. Scale as in Fig. 11. 2. Sublateral view of base and palp of mandible of male paratype. Scale equals 0.03 mm. 3. Maxillary palp and base of male paratype from medial side. Mounted in hyrax; respiratory plate omitted. Scale as in Fig. 2. 4. Portion of copulatory complex of male paratype. Scale as in Fig. 2. CA—clasper apparatus, DF—dorsal finger, DP—distal portion of the base, VF—ventral finger. 5. Clasper apparatus of copulatory complex of male holotype. Scale as in Fig. 2.

of the distal end of the shortest terminal claw. The ventral claw, which is distally curved, has a length approximate to twice the greatest width of the antepenultimate podomere. The dorsal claw has a basal portion or stalk showing great variability in shape and weight. The claw ends distally in an enlarged, flattened surface which bears along each lateral margin about ten teeth. These teeth are somewhat heavier and more conspicuous than are the teeth of the ventral claw. The shortest claw reaches just to the proximal end of the flattened surface of the dorsal claw, is located medially of the other two, and bears about fifteen teeth along the distal four-fifths of the claw. These teeth are comparable in length to those of the dorsal claw. This shortest claw is almost one-half as long as the ventral claw.

With respect to the mandible (Fig. 2), the respiratory plate is represented by three setae, of which two are subequal in length and the third is much shorter. The basal portion of the mandible has six multicuspid teeth along the cutting edge, the number of cusps varying from one or two at one end to five at the other end. The surface of the mandibular protopodite bears on the convex surface between the distal teeth and the juncture of the palp a heavy blunt spine directed distally. The mandibular palp consists apparently of four partly fused podomeres. From the flexor-distal corner of the basal podomere extends a long, slender seta along the concave side of the appendage. While the joint or suture at the distal end of the basal podomere is very weak, it is much more marked than the suture between the antepenultimate and penultimate podomeres. The penultimate podomere bears distally on the submedial surface a weakly feathered spine which reaches beyond the base of the terminal spine of the palp and, in addition, on the subextensor margin, a short distance removed from the distal end, a long, thin seta which extends nearly to the end of the terminal spine of the palp. The ultimate podomere bears a heavy spine measuring in length almost twice the length of the podomere. This large terminal spine seems to be finely serrate and somewhat spatulate in shape in the ventral view. At the base of this spine, on the flexor side, there are two long slender spines, the paired condition of which is difficult to distinguish in side view. The maxilla (Fig. 3) bears an unsegmented palp ending distally in two long spine-like setae, the ventral one of which is heavier than the more distal one although both have about the same length. The palp bears on the dorsal or convex surface, slightly distal to the midpoint, a curved seta which extends distally well beyond the base of the terminal spines of the palp. The protopodite is shorter than the palp and ends distally in two slightly curved setae which reach almost to the distal end of the palpal spines. The respiratory plate of the maxilla has from sixteen to eighteen setae.

Figs. 6-10. *Entocythere equicurva* sp. nov. 6. Right valve of shell of male holotype. Scale equals 0.2 mm. 7. Dorsal antennal claw of male paratype. Scale as in Fig. 6. 8. End of maxillary palp of male paratype. Scale equals 0.01 mm. 9. End of base and clasping apparatus of the copulatory complex of male paratype. Scale as in Fig. 2. 10. Clasping apparatus of copulatory complex of male holotype. Scale as in Fig. 2.

Fig. 11. *Entocythere dorsotunda* sp. nov. Right valve of shell of male holotype. Scale equals 0.3 mm.

Each of the thoracic legs consists of four podomeres. In the legs of the first pair, the basal podomere bears on the anterior-distal corner two setae, the medial one of which is about one-third of the length of the lateral. A single seta occurs in this position in the legs of the two posterior pairs. The antepenultimate or second podomere bears on the anterior surface in each leg a single spine-like seta removed from the distal end of the podomere by a little more than the width of the podomere at the base of the seta. This seta has a length slightly in excess of the width of the podomere at the base of the seta as far as the second and third pairs of legs are concerned but in each of the first pairs of legs, the seta has a length about one and one-half as great. The penultimate podomere in each instance has a greater distal than proximal width and bears on the anterior distal corner a seta which is subequal to the length of the nearly square ultimate podomere. The teeth of the sickle-shaped terminal claws appear to be five in number, with the center tooth conspicuously longer than any of the others.

The most distinctive diagnostic structures of this species are found in the shape of the distal portion of the base and the nature of the clasping apparatus of the male copulatory complex. The former (Fig. 4) is peculiar since the distal end of the base is narrowed and extended to form a long, gently curved process which parallels in part the proximal portion of the clasping apparatus. The proximal and distal portions of the base are poorly separated. Attached to the former are the two fingers and the clasping apparatus. The fingers are not unusual, the dorsal being short and somewhat fleshy with a terminal spine nearly equal in length to the basal portion of the finger. The ventral finger is long and slender with the spine extending beyond the end of the clasping apparatus. With regard to the clasping apparatus (Figs. 4, 5), the short vertical ramus is proximally little curved. The horizontal ramus is little longer than the vertical with the entire external border divided into a fairly straight proximal portion and a slightly convex distal portion, the two portions meeting somewhat abruptly. The regularly curved internal border bears in most cases four well spaced teeth. Terminally, the clasping apparatus becomes narrowed and the distal margin bears two or three very small teeth more or less continuous with the teeth of the internal border. A talon is wanting. In many individuals, a conspicuous penis is present in the distal portion of the base at or distal to the level of the proximal end of the clasping apparatus.

Female.—The shell of the female is similar to that of the male except that in the gravid female (recognized by the divided condition of the penultimate podomere of the antenna and the three antennal claws) the posterior-ventral region of the shell is slightly swollen. The sizes of the shells of several of the gravid females mounted in clarite or hyrax are as follows:

Length	Height	
0.51 mm.	0.31 mm.	(paratype, clarite)
0.52	0.29	(paratype, hyrax)
0.50	0.30	(paratype, clarite)

The copulating females (those which have only four antennal podomeres and two end claws) are slightly smaller than the gravid females. There are few of the copulating type in the collection.

The cephalic appendages of the gravid female differ little from those of the male except in the instance of the antenna in which there are a few differences in the shape of the end claws and in the length of setae. The seta of the second podomere is slightly shorter in the gravid female while the setae of the basal portion of the penultimate podomere are more nearly equal in length than in the male. The end claws are in no way peculiar to females of this genus, the shortest being slender and having a length about one-half of the longest. Like the antennules, the mandible and maxilla do not show sexual dimorphism. The thoracic legs are almost identical in males and in gravid females except that the two setae of the distal end of the basal podomere of each first thoracic leg are nearly equal in length, both reaching nearly to the base of the spine of the antepenultimate podomere of the leg. External sexual structures were not observed in the individuals studied.

Since only a very few of the copulating type of females were found in the collections and none were taken while actually in copulation, no study could be completed of the appendages except to note that the penultimate podomere of the antenna is biunguis.

Distribution and Ecology.—Known only from the type locality.

Remarks.—The simple nature of the clasping apparatus of *E. serrata* sets off this from related forms with which it might be confused. Its closest related species are probably *E. columbia* Dobbin 1941, *E. riojai* Hoff 1943, *E. humesi* Hoff 1943, *E. dobbinae* Rioja 1944, and *E. equicurva* sp. nov., in all of which the clasping apparatus has no talon and the horizontal ramus is dentate along the internal border. Besides separation from other species by the characteristics of the clasping apparatus as given in the key, *E. serrata* may be differentiated from related species as follows: from *E. riojai* and *E. dobbinae* by the greater shell size and by the presence of a spine on the convex surface of the palp of the maxilla; from *E. dobbinae* and *E. columbia* by the presence of a greater number of respiratory setae on the maxilla; from *E. columbia* by the lack of the posterior shell projection found in the latter; from *E. equicurva* by the shell size and the longer spine on the convex surface of the maxillary palp; from *E. humesi* by the presence of a spine on the convex surface of the palp of the maxilla.

Entocythere equicurva sp. nov.

Figs. 6-10

Type specimens of this species were taken from crayfish of the species *Procambarus paeninsulanus* collected by Hobbs about 2.3 miles south of Woodbine, Camden County, Georgia, on September 8, 1938. The name of this species is suggested by the more or less evenly curved clasping apparatus. Holotype (male), allotype (female), and paratypes (both sexes), U. S. N. M.

Male.—The shell (Fig. 6) is oval in form with the dorsal, posterior, and anterior margins rounded. Each margin blends into the adjoining one without demarcation except for a slight angle at the juncture of anterior and dorsal margins. The anterior and posterior ends of the shell show little differ-

ence in shape and the ventral margin is nearly straight. The shell is well pigmented, especially in the central portion of the dorsal one-half of each valve. The eye is oval, deeply pigmented, and is located within the anterior one-fourth of the body. Shells of several males (mounted in clarite) measure as follows:

Length	Height	
0.34 mm.	0.19 mm.	(holotype)
0.30	0.17	(paratype)
0.32	0.18	(paratype)

Examination of males from collections other than the type collection reveals no significant variations in size, shape, or pigmentation of the shell.

Each antennule is composed of six podomeres of which the first is longer and the third shorter than the others. The single seta on the flexor-distal corner of the basal podomere has a length less than the length of the second podomere. The second podomere bears a single seta; the third podomere has two; the fourth, six; the fifth, none; and the sixth has five terminal setae. Each antenna is stout and is composed of four podomeres of which the penultimate is divided. The second podomere is almost as wide as long and bears a seta which does not extend beyond the base of the seta of the distal portion of the penultimate podomere. The longer seta of the distal pair of the basal part of the penultimate podomere does not extend beyond the end of the penultimate podomere while the seta of the distal portion is located near the distal one-third and has a length no greater than the length of the part of the podomere that bears it. The terminal claws are not unusual. The ventral one is slender and tapers gradually from the widened proximal part of the slender, slightly curved tip. The claw bears ten to twelve poorly developed teeth. In a few individuals, the ventral claw is slightly S-shaped resulting from a secondary curvature near the base. The dorsal claw (Fig. 7) is stout and bears about ten teeth on the flattened terminal portion. The distal tooth appears to be continuous with a distal extension of the tip of the claw. The medial claw, although it bears a few more teeth than the dorsal claw, reaches scarcely beyond the beginning of the flattened area of the dorsal claw.

The mandible in this species has a relatively slender protopodite ending distally in six slender teeth, the largest of which has five cusps while three of the others are tricuspid and two appear unicuspid. Beyond the two unicuspid teeth in some individuals, there appears to be a small additional but rudimentary tooth. Three setae represent the respiratory plate. On the convex surface of the protopodite, there is a slender but not very conspicuous seta. No indication of segmentation except the demarcation of the distal podomere can be noticed in the palp. On the flexor side of the palp, possibly at the point where the suture between the first and second podomere usually occurs, there is a long seta which extends distally and parallel to the podomere for some distance and then is markedly curved away from the palp. Removed a short distance from the distal end of the penultimate podomere and somewhat lateral in position is a long seta which extends beyond the tip of the terminal spine of the palp. On the extensor surface of the same podomere and almost distal in position, there is a short spine-like seta which extends but little beyond the distal

end of the ultimate podomere. The ultimate podomere of the palp tapers but little terminally where it bears a heavy, somewhat spatula-like spine nearly one and one-half times as long as the ultimate podomere. On the flexor side of this spine, there is a pair of small setae, each of which extends but little beyond the midpoint of the terminal spine. The maxilla has a respiratory plate of eighteen setae. The base or protopodite is very short and bears a pair of long setae, each but little curved and reaching to about the midpoint of the terminal spines of the palp. The palp (Fig. 8) is unjointed. It has a seta on the convex surface and terminates in two spines, of which the longer is about equal in length to the length of the palp. The smaller, more dorsal spine is less heavy in appearance and reaches almost to the tip of the heavier spine.

The thoracic legs present no unusual structures. One of the two setae of the anterior-distal corner of the basal podomere of the first leg reaches approximately to the base of the seta of the antepenultimate podomere while the other is not over one-half of this length. The penultimate podomere of each leg bears a weakly feathered seta. Each end claw has five teeth.

The most important species characteristics are furnished by the copulatory organs or complex. The proximal portion of the base is triangular, the shortest side being dorsal, the longest side adjoining the distal part of the base, while the third side forms a slightly convex free margin. The distal portion of the base is about twice as long as the proximal portion. The longer free margin of the distal portion of the base is convex but displays two or three shallow sinuations which give the margin an undulating appearance. Terminally, the distal margin of the base (Fig. 9) is rounded and meets in an obtuse point the margin lying approximate to the clasping apparatus. A conspicuous penis is present in the distal portion of the base some distance from the terminal margin. The clasping apparatus (Figs. 9, 10) is sickle-shaped and more or less evenly curved throughout as the name "equicurva" implies. This clasping apparatus has nearly the same width throughout except that distal to the teeth of the internal border, the horizontal ramus gradually tapers to about one-half the more proximal width. The teeth of the internal border are located about midway between the juncture of the horizontal and vertical rami and the distal end of the horizontal ramus. While there is considerable variation in the length of the part of the horizontal ramus terminal to the teeth, this variation appears to be individual in nature and not racial as indicated by the fact that in some individuals the part in question is very long and slender on one side of the body but much stouter on the opposite side. The teeth are typically two in number with the development of a rudimentary third tooth in some individuals. The proximal tooth is always the larger. The external border of the clasping apparatus is entire. The distal margin of the clasping apparatus is divided to form two or three poorly developed teeth along the truncate end. Variation is evident in these teeth which appear practically non-existent in some individuals. The dorsal finger consists of a base and a spine, the latter being about one-half as long as the former. The ventral finger reaches to the end of the clasping apparatus and is either gently curved throughout its length or greatly curved at the end and almost straight in the center. The terminal spine is subequal to the spine of the dorsal finger.

Female.—The shell of the gravid female differs little from the shell of the male except that the posterior portion is often somewhat swollen, resulting in a slightly concave ventral margin. The size of the shell is about ten per cent greater than that of the male, the length varying from 0.34 mm. to 0.37 mm. and the height from 0.21 mm. to 0.25 mm. in the type material.

In general, the appendages of the gravid female resemble closely those of the male. The antennules are practically identical. There are some differences in the antenna since this appendage shows sexual dimorphism. The seta of the second podomere extends nearly to a level with the tips of the subequal setae of the pair of the proximal part of the antepenultimate podomere. These in turn reach beyond the base of the single seta of the distal part of the penultimate podomere. A single seta originates from near the midpoint of the flexor surface of the distal portion of the podomere and scarcely reaches beyond the end of the ultimate podomere. The ventral terminal claw has a slightly swollen base, tapers gradually to an acute, curved point, and bears twelve or more conspicuous teeth. The dorsal claw is more slender than the ventral and slightly shorter but has about the same general shape. The teeth of the dorsal claw are few in number and poorly developed. The medial claw is extremely slender and inconspicuous, being little more than one-third the length of the ventral claw. Teeth could not be distinguished on the medial claw. The mandibles and maxillae of the gravid female appear identical with those of the male as do also the thoracic legs with the exception of the pair of setae on the anterior-distal corner of the proximal podomere of each first leg. In the female, these setae are equal or nearly equal in length, never showing the difference conspicuous in the male.

The copulating female has a shell much like that of the male in general outline except that the posterior part of the shell is no higher, and often not so high, as the anterior part. The margins are entire and evenly arched, although the ventral margin is not markedly convex. The shell of the copulating female measures in general about ten per cent less in length than the shell of the male. Except for the antennae and slight differences in lengths of setae and length:width ratios of podomeres, the appendages of the two types of females are identical. The antenna of the copulating female has two end claws and has the penultimate podomere undivided. Near the center of the penultimate podomere, there is a pair of setae, distal of which there is a third seta with a length much in excess of either of the setae of the pair. Females in copulation were abundant in the type material.

Distribution and Ecology.—*E. equicurva* is found frequently in collections from the southeastern United States. Besides the occurrence of the species in the type collection, the form has been taken in ten collections from Florida and one from Alabama. The species of crayfishes and the number of collections of each species from which the material was taken are *Orconectes spinosus* (1, Alabama), *Procambarus leonensis* (1), *P. fallax* (3), *P. kilbyi* (1), *P. lucifugus alachua* (2) and *P. paeninsulanus* (3).

Remarks.—The C-shaped clasping apparatus is sufficient to separate *E.*

equicurva from all species except the closely related species *E. dobbiniae*, from which separation may be made by the presence of the spine on the convex surface of the maxillary palp and the greater number of setae in the respiratory plate of the maxilla.

***Entocythere dorsorotunda* sp. nov.**

Figs. 11-14

Individuals of this species were secured from jars containing crayfishes of the species *Procambarus advena* and *P. alleni* collected from several localities in Florida and Georgia. The species name is suggested by the entire, evenly rounded dorsal margin of the shell. Holotype (male), allotype (gravid female), and paratypes (both sexes), U. S. N. M.

Male.—The shell is elliptical in shape with all margins, including the ventral one, convex. The posterior part of the shell is much broader than the anterior. There is a very slight break in the arc of the anterior margin near the midpoint but this interruption is not marked. The circular eye is located slightly more than one-fifth of the length of the shell from the anterior end. The sizes of the shells of several males mounted in clarite are as follows:

Length	Height	
0.43 mm.	0.24 mm.	(holotype)
0.42	0.25	(paratype)
0.44	0.24	(paratype)
0.46	0.26	(paratype)
0.44	0.24	(paratype)
0.43	0.23	(paratype)

Each antennule is composed of six podomeres which decrease in width from the basal to the distal end of the appendage. The various podomeres are nearly equal in length with exception of the basal podomere which is considerably longer than any of the others. Distally the basal podomere bears, nearly flexor in position, a spine subequal in length to the length of the second podomere. The second podomere bears a long flexor-distal seta and a very short spine (difficult to detect) on the extensor-distal corner; the third podomere bears two long distal seta, one on the medial side and one on the flexor surface. The fourth or the antepenultimate podomere bears six distal setae arranged about the margin of the podomere. Two of these are near the flexor-medial corner and extend beyond the end of the ultimate podomere. The penultimate podomere is free of setae but the ultimate podomere bears five setae, one of which is much shorter than the others.

In comparison, the terminal claws of the antenna (Fig. 12) are relatively much longer and more slender than those of most species of the genus. The flexor or ventral claw has a length of approximately one and one-half times the length of the distal portion of the penultimate podomere of the antenna. The flattened flexor surface of the dorsal claw is very long and slender. The shortest claw reaches to a point distal to the beginning of the flattened surface of the dorsal claw. The teeth of these claws are well developed, there being about fifteen comb-like teeth on the flattened distal end of the dorsal claw.

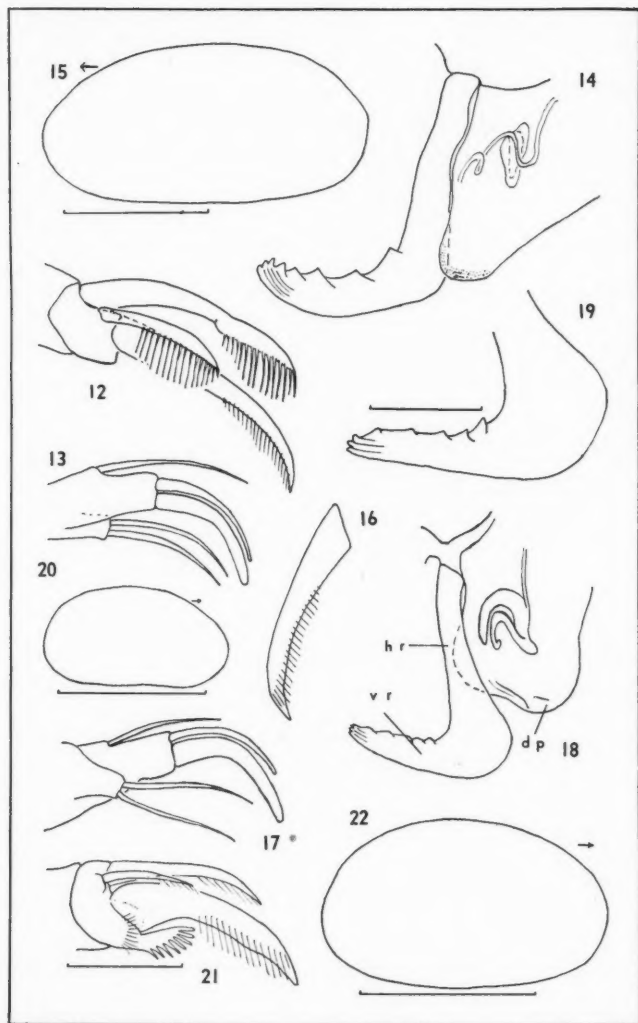


PLATE 2: Figs. 12-14. *Entocythere dorsorotunda* sp. nov. 12. Medial view of antennal claws of male holotype. Scale as in Fig. 19. 13. Palp and base of maxilla of male holotype. Scale as in Fig. 19. 14. Clasper apparatus and end of distal lobe of copulatory complex of male holotype. Scale as in Fig. 19.

Figs. 15-21. *Entocythere elliptica* sp. nov. 15. Outline of shell of male paratype.

There are up to as many as twenty teeth on the median or shortest claw while the ventral claw has as many or more teeth than the median claw. These are, however, not so long or conspicuous as the teeth of the dorsal claw. The flagellum (exopod) of the antenna does not reach the level of the end of the terminal claws. The antepenultimate podomere bears on the flexor-distal corner a single seta which reaches the level of the base of the seta of the distal portion of the penultimate podomere. In the divided penultimate podomere, the basal portion bears two setae on the flexor-distal corner. Of these, the more lateral one is long and extends usually to the distal end of the last podomere of the antenna; the second and more medially placed has a length about two-fifths of the length of the first. The distal portion of the penultimate podomere bears on the flexor surface near the center a seta which extends well beyond the end of the ultimate podomere. The distal portion of the penultimate podomere is somewhat shorter than the proximal portion.

The mandible has a protopodite which, as far as could be observed in the present material, bears only two setae representing the respiratory plate. On the concave (dorsal) edge of the protopodite, there is a spine anterior to the midpoint between the distal chewing surface and the origin of the palp. This spine has a length approximate to the width of the protopodite at the point of attachment of the spine. The teeth of the chewing edge are relatively longer than in many species. Of the six teeth, the inner one is long, acute, and unicuspid; the center ones each have two or three cusps; and the outer tooth is distally cleft nearly to the base into a blunt structure bearing five cusps and a shorter more pointed structure. This latter lies to the outside, can be seen only in lateral view, and in some individuals seems to be secondarily cleft. The palp is similar to the palp of related species. On the flexor surface at what is perhaps the distal end of the first palpal podomere, there is a long seta, evenly curved, and reaching to the end of the terminal podomere of the palp. A suture or joint is not evident at this point. Between this seta and the next more distal seta, which is located on the extensor surface at about the midpoint of the podomere which bears it, is a very weak suture which no doubt represents the juncture of the second and third palpal podomeres. The longer seta of the third podomere reaches at least to the tips of the terminal claws. Ordinarily it extends away from the palp rather than along the extensor surface. On the inner distal corner of the third podomere is a seta which extends to a level with the center of the distal claws. Terminally the ultimate podomere bears a heavy, claw-like spine which has a length almost twice that of the ultimate

Scale equals 0.25 mm. 16. Ventral antennal claw of male paratype. Scale as in Fig. 21. 17. Maxillary palp and base of male paratype. Scale as in Fig. 19. 18. Clasper apparatus and part of base of copulatory complex of male holotype. Scale as in Fig. 21. DP—distal portion of the base, HR—vertical ramus, VR—horizontal ramus. 19. Horizontal ramus of the clasper apparatus of the copulatory complex; male paratype. Scale equals 0.02 mm. 20. Outline of shell of female allotype. Scale equals 0.5 mm. 21. Medial view of ultimate podomere and end claws of the antenna of female paratype. Scale equals 0.03 mm.

Fig. 22. *Entocythere talulus* sp. nov. Outline of the left valve of the male holotype. Scale equals 0.2 mm.

podomere. Beneath the terminal spine is a pair of setae, each of which is nearly as long as the spine.

The maxilla (Fig. 13) is not unusual. There appears to be seventeen or eighteen setae in the respiratory plate; the very short protopodite ends distally in two setae; and the palp is unsegmented through the complete fusion of the podomeres. At the level of what is perhaps the union of the penultimate and ultimate podomeres on the extensor side of the palp, there is a seta which reaches to the center of the terminal spine of the palp. Distally, the palp bears a long, gently curved spine above which is a more slender, subequal spine or seta. With respect to the thoracic legs, the basal podomere bears, in the instance of the first pair of legs, two setae, the lateral one of which has over twice the length of the medial one. In the legs of the second and third pairs, there is a single seta at this point. The seta of the antepenultimate podomere of each leg has a length at least one and one-half times the width of the podomere at the base of the seta while the seta of the anterior-distal corner of the penultimate podomere is spine-like. Each leg bears a terminal claw with six or seven teeth.

The copulatory organ (Fig. 14) has a long, narrow distal portion of the base which terminates in a blunt, somewhat chitinous lobe. The dorsal finger is relatively long and ends in a spine at least two-thirds as long as the base. The ventral finger is sickle-shaped and evenly curved throughout most of the length. The terminal spine of the ventral finger is subequal in length to the spine of the dorsal finger and extends beyond the end of the horizontal ramus of the clasping apparatus. The clasping apparatus has a nearly straight vertical ramus joined at more than a right angle by the horizontal ramus, forming an L-shaped clasping apparatus. The horizontal ramus is proximally straight but terminally curved with respect to the external border. The internal border and the terminal or distal margin bear together eight teeth. Of these, five are large and are spaced along the internal border. The teeth belonging to the distal margin are much smaller. There is no talon.

Female.—The shell of the gravid type female is very similar to that of the male but the posterior-ventral portion is so swollen that the ventral margin of the shell is straight or, in some instances, shows a very slight concavity just anteriorly to the center of the shell. The posterior end of the shell is much wider than the anterior and has the margin slightly flattened through a part of its extent. The lengths and heights respectively of two females mounted in clarite are as follows: 0.43 mm. and 0.24 mm. (allotype); 0.42 mm. and 0.25 mm. (paratype). The appendages of the gravid female differs little from those of the male. The antennal claws, especially the ventral one, are relatively longer than in most species of *Entocythere*. The antenna has the penultimate podomere divided. The two distal setae of the basal portions are subequal, each hardly reaching to the distal end of the penultimate podomere. The chaetotaxy of the antennule is the same as in the male and the mandibles and maxilla are likewise similar. The setae of the distal-anterior corner of the proximal podomere of the first legs are almost equal in length, both being very long and reaching to the base of the seta of the antepenultimate podomere.

Only a single female was found in copulation. The shell of this individual measures 0.41 mm. in length and 0.22 mm. in height. The ventral margin is weakly convex. The posterior part of the shell is slightly wider than the anterior while the posterior-dorsal corner is somewhat angular. This last characteristic, however, may result from fixation and more females of this type taken during copulation are needed before description can be completed. The antenna of this female has an undivided penultimate podomere and two nd claws. A study of the other appendages of the copulating female could not be made because the animal was not mounted in a dissected condition. In some collections containing this species, other females with two antennal claws were found, but it was thought hazardous to use these in description of the form since they were not taken during copulation and they occur in collections containing individuals of more than one Entocythere species.

Distribution and Ecology.—*E. dorsorotunda* sp. nov. was found in six collections from Georgia and Florida. Specimens were taken in three instances from *Procambarus advena* collected near Fitzgerald, Ben Hill Co., Georgia, on April 14, 1939 (holotype and paratypes); near Blackshear, Pierce Co., Georgia, on March 27, 1939 (paratypes); and from the farm of H. C. Smith, Clay Co., Florida, on Dec. 26, 1936 (paratypes). One collection was from *P. alleni* taken from burrows in a marsh in Miami, Dade Co., Florida, on July 15, 1937 (allotype and paratypes) and a second from Englewood, Charlotte Co., Florida, on Feb. 2, 1936. One male and possibly some females were also secured from *P. seminolae* near Fargo, Clinch Co., Georgia, on Oct. 27, 1938.

Remarks.—The peculiar shape of the clasping apparatus of *E. dorsorotunda* allows ready identification of the species. While the heavy, sharp dentations of the internal border of the clasping apparatus resemble to some extent the condition found in *E. claytonhoffi* Rioja 1942 and *E. mexicana* Rioja 1944, differences tend to minimize the possibility of this resemblance being an expression of natural relationship. The lack of an accessory process on the ultimate podomere of the antenna of the female as well as the smaller size serves to distinguish the present species from both *E. claytonhoffi* and *E. mexicana*.

Entocythere elliptica sp. nov.

(Figs. 15-21)

This somewhat unusual Entocythere is common in collections from Florida and Georgia. Some type specimens (holotype, allotype, and paratypes) were secured from the crayfish *Procambarus seminolae* taken north of Fargo, Clinch County, Georgia, on Oct. 27, 1938, by Young and Hobbs while other type specimens (paratypes) were secured from *P. alleni* taken by Martin and Hobbs near Orlando, Orange Co., Florida, on Nov. 11, 1938. The species name is suggested by the elliptical shape of the shell. Holotype (male), allotype (gravid female), and paratypes (both sexes), U. S. N. M.

Male.—The shell (Fig. 15) of the male is regularly elliptical in shape except for a slight angle at the juncture of the dorsal and the posterior margins. The anterior end is well rounded and but little narrower than the

posterior end. The ventral margin is almost straight, a slight sinuation being displayed in some shells near the anterior one-third. The eye is large, usually oval in shape, and located about one-fifth of the distance from the anterior end. The shell of this species is usually poorly pigmented. The sizes of shells of several males mounted in clarite are as follows:

Length	Height	
0.53 mm.	0.28 mm.	(holotype)
0.53	0.27	(paratype)
0.56	0.28	(paratype)
0.51	0.25	(Gulf Co., Fla.)
0.51	0.28	(McIntosh Co., Ga.)

Each antennule is composed of six podomeres, subequal in length except for the first and fourth podomeres which are slightly longer than the others. The basal podomere bears distally one seta, the second bears a single seta on the medial-distal corner; the third podomere bears two setae on the distal margin, one flexor in position and the other median; the fourth podomere displays six setae; the fifth is devoid of setae; while there are five terminal setae on the ultimate podomere.

The antennae are not unusual except for the ventral claw. The antepenultimate podomere is little longer than wide and its distal-flexor seta extends about to the end of the base of the seta of the terminal portion of the penultimate podomere. The two portions of the penultimate podomere are nearly equal in length. The basal portion bears distally on the flexor corner two setae, one of which is slightly longer than the other. The shorter one extends but little beyond the base of the seta of the distal portion of the penultimate podomere. This last mentioned seta lies near the center of the flexor surface of the distal part of the penultimate podomere and reaches beyond the end of the ultimate podomere. Not far from this seta, at the same level, but medial in position, is found a slender spine which does not reach to the distal end of the podomere that bears it. The terminal claws are three in number. The dorsal bears ten to twelve heavy teeth along the flattened terminal surface; the stalk-like proximal portion of the claw is evenly arched and slender. The medial claw bears usually about twelve teeth and reaches just beyond the proximal corner of the flattened area of the dorsal claw. The ventral claw (Fig. 16) is relatively heavy and bears along each side the customary row of fine teeth, probably about twenty on each side. Terminally, these teeth originate some distance from the ventral edge of the claw so that the hyaline tip appears chisel-like and extends beyond the row of teeth. There is nothing unusual about the ultimate podomere of the antenna in the male.

The mandibular protopodite bears six acute, long teeth which are more slender than in most Entocythere species. The teeth have few, poorly developed irregular cusps. Between these teeth and the base of the palp, but closer to the former, is a short spine on the convex edge of the protopodite. The respiratory plate is represented by three long setae. The podomeres of the palp are to a considerable extent fused but the distal-flexor corner of the basal one is indicated by a long seta which extends to the level of the distal end of the ultimate podomere of the palp. A poorly developed suture is present (observ-

able in stained specimens) between the second and third podomeres. The third or the penultimate podomere bears on the distal extensor corner a stout spine which has a length slightly greater than twice the length of the ultimate palpal podomere. Near the extensor surface, but slightly medial and somewhat distal to the midpoint of the podomere, there is a long seta which extends almost to the tip of the terminal spine of the palp. The ultimate podomere is about as long as its basal width and bears a heavy spine below which are two setae subequal in length to the terminal spine. With respect to the maxilla (Fig. 17), the short and fleshy protopodite bears distally two long but gently curved setae. The podomeres of the palp are fused. The palp is much longer than the base of the appendage and terminates in a heavy spine equal to or greater in length than the palp itself. The spine is well curved and along its convex side, there is a much weaker and shorter spine. On the convex surface of the palp is an additional seta removed from the end of the palp by a distance equal to a little more than the width of the palp at the base of the seta and having a length equal to twice the width of the palp. The respiratory plate bears usually eighteen or nineteen well developed setae.

The three pairs of legs are similar to those of other Entocythere species. The anterior-distal corner of the first podomere of each leg of the first pair has two setae; the shorter of the two setae being from one-third to one-half the length of the longer. The longer seta is conspicuously feathered. On the first podomere of each of the other legs, there is a single feathered seta. The antepenultimate podomere of the posterior pair of legs is very long and slender with a spine-like seta on the anterior surface removed from the end by about the width of the podomere. This seta, as well as those of the corresponding podomere of other legs, is not conspicuously, if at all, feathered. The seta on the anterior-distal corner of the penultimate podomere of each leg is in every instance feathered. The end claw of each leg has few teeth, one relatively slender and short tooth lying on the outside and two on the inside of the longest or principal tooth.

The copulatory apparatus or complex has a triangular proximal portion of the base while the distal portion of the base is elongated but does not measure much over one and one-half times the length of the proximal portion. The distal end of the distal portion of the base (Fig. 18) is truncate, being flat or weakly concave. The dorsal finger has a base scarcely longer than the terminal spine which appears bifurcated. The ventral finger is in the form of a long curved rod which roughly parallels the internal border of the clasping apparatus. The base of the ventral finger reaches to the end of the clasping apparatus but the spine extends beyond. The terminal spine of the ventral finger is heavier but slightly shorter than that of the dorsal finger. The clasping apparatus has a bar-like vertical ramus, with the internal border proximally convex. The external border is concave because the juncture of the vertical and horizontal rami is swollen. The vertical ramus lies at less than a right angle to the horizontal ramus and the latter is shorter than the former. The external border of the horizontal ramus (Figs. 18, 19) is slightly convex and entire; the internal border is almost straight and exhibits five teeth, the more distal or terminal

ones being less acute, not so high, and more widely spaced than the proximal ones. The horizontal ramus becomes gradually narrowed toward the tip. The distal margin has three small, closely spaced teeth.

Female.—The shell of the gravid female (Fig. 20) is larger and not so regularly elliptical as that of the male. The anterior end is considerably narrower than the posterior end, being in fact somewhat pointed. The ventral margin of the shell is slightly concave, with the deepest part of the concavity at about the anterior two-fifths of the shell. The shell is slightly swollen both before and behind the concavity. The highest point of the dorsal margin is near the center and the anterior slope is much more pronounced than the posterior. The posterior margin joins the ventral and dorsal margins without interruption. Pigmentation is similar to that of the male.

Shell of several gravid females mounted in clarite measure as follows:

Length	Height	
0.64 mm.	0.35 mm.	(allotype)
0.53	0.35	(paratype)
0.60	0.32	(Effingham Co., Ga.)

The appendages of the gravid female differ from those of the male mainly in the structures which usually display sexual dimorphism in species of *Entocythere*. The chief differences are concerned with the antennae. The seta of the distal-flexor corner of the antepenultimate podomere reaches but little beyond the insertion of the pair of setae of the proximal portion of the penultimate podomere. The basal portion of the penultimate podomere has distally and on the flexor surface two subequal setae which do not reach to the level of the ultimate podomere of the antenna. The distal portion of the penultimate podomere has near the center of the flexor surface a seta which extends to the base of the terminal claws. The ultimate podomere (Fig. 21) is very peculiar since it bears close to the flexor-distal margin a subspatulate structure as long as the greatest length of the podomere. This structure has about eight comb-like teeth along the ventral side and around the end, while the side toward the ventral claw is entire. Proximal to this structure and along the medial-terminal margin of the ultimate podomere, somewhat toward the flexor side, is a band-like row of twelve to fifteen minute teeth. The ventral claw itself is very heavy and stout, having a length approximately equal to the length of the distal portion of the penultimate podomere. The claw is peculiar since, like the same claw in the male, the tip is shaped like a knife blade or a chisel and extends beyond the row of teeth of each side. The dorsal claw has a length little more than two-thirds that of the ventral while the medial claw is little more than one-half as long as the dorsal. Both the dorsal and medial claws are exceptionally slender and bear fine and inconspicuous teeth.

The antennules, mandibles, and maxillae are similar to the same structures in the male. The legs are likewise similar in the two sexes except for the pair of setae of the basal podomere of the first pair of legs. These are subequal in the female, each being nearly equal to two-thirds of the antepenultimate podomere of the leg which bears it. Both setae are feathered.

No females were seen in copulation. Several immature females were found, however. These were recognized as immature by the undivided condition of the penultimate podomere of the antenna and the two terminal claws and as females by the accessory structure of the ultimate podomere of the antenna. This structure, however, in the copulating female is not elongated but resembles a short, blunt spatula with seven to nine teeth along the distal margin. The band-like row of teeth along the ultimate podomere is wanting. Of the terminal claws, the dorsal one is slender and finely toothed while the ventral is very stout at the base and shows at the tip the chisel-like extension seen in the same claw of the gravid female. The shell of the copulating female is regularly elliptical except for a slight ventral sinuation at about the end of the anterior one-third of the shell. The shell size is about ten per cent less than the shell of the gravid female.

Distribution and Ecology.—Besides the type locality, specimens of *E. elliptica* have been secured from twenty-four localities in Florida and Georgia and one locality in Hampton County, South Carolina. The crayfish from which this species of Entocythere was secured included *Cambarus versutus* (2), *Procambarus alleni* (2), *P. apalachicola* (1), *P. seminola* (3), *P. barbatus* (3), *P. blandingii acutus* (1), *P. fallax* (2), *P. kilbyi* (1), *P. lunzi* (1, South Carolina), *P. paeninsulanus* (6), *P. pubescens* (1), *P. clypeata* (1), species undetermined (1). The numbers in parentheses indicate the number of collections from each species of crayfish.

Remarks.—By the accessory process on the ultimate podomere of the antenna of the female and the general nature of the clasping apparatus of the male, relationship is indicated between *E. elliptica* and each of the following: *E. claytonhoffi* Rioja 1942, *E. illinoisensis* Hoff 1942, and *E. mexicana* Rioja 1944. *E. elliptica* can, however, be separated from the other related forms by the more angular shape of the clasping apparatus, the more elliptical shape of the shell, and the larger number (18 or 19) of setae in the maxillary respiratory plate.

Entocythere talulus sp. nov.

Figs. 22-25

A number of individuals of this species were found in a single collection of the crayfish *Procambarus alleni* collected from burrows under boards in a marsh at NW 20th Street and 27th Avenue, Miami, Dade County, Florida, on July 15, 1937. The name "talulus" is the diminutive of "talus" and is suggested by the rudimentary talon or heel of the horizontal ramus of the clasping apparatus. Holotype (male), allotype (gravid female), and paratypes (both sexes), U. S. N. M.

Male.—In general outline, the shell (Fig. 22) of the male is oval with the posterior end slightly wider than the anterior. Both the dorsal and ventral margins are convex, the former more so than the latter. Both margins pass without interruption into the evenly curved anterior margin. The posterior margin is slightly flattened dorsally, displays an abrupt change in arc just below the midpoint, and passes without interruption into the ventral margin.

The eye is circular in outline and is placed more than one-fourth of the shell length from the anterior end of the shell. The shell of the male is not heavily pigmented but in some specimens there may be irregular pigmented areas especially near the dorsal-central part of the shell. The sizes of several shells of males mounted in clarite are as follows:

Length	Height	
0.33 mm.	0.20 mm.	(holotype)
0.34	0.21	(paratype)
0.33	0.19	(paratype)

The antennules are not conspicuously different from those of other species of the genus, being composed of six podomeres of which the third podomere is conspicuously shorter than any other. The penultimate podomere is decidedly narrower than the antepenultimate podomere. The basal podomere bears a single relatively short seta on the flexor-distal corner; the second podomere has a single seta medial and distal; the third has two seta, one medial-distal and the other extensor-distal in position; the fourth or antepenultimate podomere has six setae; the penultimate has none; while the ultimate podomere supports five setae. The antenna has four podomeres, of which the penultimate is divided. The antepenultimate podomere is but little longer than wide and bears a heavy seta on the flexor-distal corner. This seta reaches to the level of the origin of the seta of the distal portion of the penultimate podomere. The setae of the pair on the distal-flexor corner of the basal part of the penultimate podomere are relatively short and subequal, not extending much beyond the base of the seta of the distal portion of the penultimate podomere. Slightly anterior to the midpoint of the flexor surface of the distal portion of the penultimate podomere, there is a relatively long seta extending nearly to the tip of the median terminal claw. Of the three terminal claws, the ventral is distally very slender, has an acute, curved tip, and bears about twelve fine teeth. The dorsal claw has an evenly curved basal portion and the flattened distal part bears ten or more comb-like teeth. The medial claw extends slightly beyond the proximal corner of the flattened area of the dorsal claw and displays teeth nearly equal in size and length to the teeth of the dorsal claw.

The protopodite of the mandible (Fig. 23) has a cutting edge of six teeth ranging in size from an acute tooth of one cusp, through several somewhat flattened teeth of three cusps, to a very wide tooth bearing five well developed cusps. Between the teeth and the insertion of the palp, there occurs a blunt spine on the convex edge of the protopodite. The respiratory plate is represented by three setae of unequal length. The podomeres, except the terminal, of the palp are fused together. On the concave side of the palp, at the point where the suture between the first and second podomeres might be expected, there is a long distally curved seta which reaches just beyond the end of the ultimate podomere. Also there is a seta near the extensor side of the palp removed from the distal end of the penultimate podomere by nearly the width of the palp at that point. This seta reaches almost to the end of the terminal spine of the palp. In addition, at the end of the penultimate podomere is a somewhat heavy spine which reaches just beyond the end of the ultimate podomere. The ultimate podomere is short and bears distally a little curved

spine having a length slightly greater than the length of the podomere. At the inner or convex side of this spine is a pair of setae subequal in length to the spine. The base of the maxilla (Fig. 24) extends but little beyond the juncture with the palp and ends distally in two long, slightly curved setae. The palp ends in two relatively weak and little curved subequal spine-like setae, the ventral one of which is stouter than the dorsal. The maxillary respiratory plate has about eighteen setae.

The legs exhibit no outstanding characteristics. Of the two setae on the distal-anterior corner of the basal podomere of the legs of the first pair, the longer of the two reaches almost to the base of the seta of the antepenultimate podomere of the leg while the shorter is one-half to two-thirds the length of the first. The seta of the basal podomere of each of the other two legs is relatively short. The seta of the penultimate podomere seems to be finely feathered and the end claw of each leg appears to have five teeth.

The male copulatory complex (Fig. 25) has several distinctive features. The proximal portion of the base is more or less triangular, with a height exceeding the width. The distal portion of the base is nearly twice as long as the proximal portion. This elongated distal portion is terminally truncate with the corner near the clasping apparatus drawn out into a sharp, acute point. Close to this point and in the base, may be seen the penis. The clasping apparatus is sickle-shaped, with the horizontal and vertical rami somewhat straightened. These are of about equal length and are connected by an evenly curved arc. The clasping apparatus is about the same width throughout, being but little enlarged at either end. The internal border is smooth except for a single acutely pointed tooth near the center of the ramus. On the external border, there are two similar and nearly equal teeth. These may be relatively feeble, often being much reduced in comparison to those of the holotype. The proximal tooth may be homologous with the talon of other species. Distal to the teeth, the ramus becomes narrowed and ends in two sharp teeth. The dorsal finger is much widened at the base and terminates in a simple spine. The ventral finger is bar-like, bent near both ends so that the finger lies roughly parallel to the clasping apparatus. Terminally, the ventral finger ends in a long spine which extends for at least one-half of its length beyond the end of the clasping apparatus. This spine is much longer than the spine of the dorsal finger.

Female.—The shell of the gravid female is similar to that of the male except that the ventral margin is slightly concave in some individuals and the anterior end often seems to be somewhat more pointed. The best identifying characteristic is the flattened dorsal portion of the posterior margin of the shell. The shell of the gravid female (allotype) mounted in clarite has a length of 0.35 mm. and a height of 0.21 mm.

The antennules and antennae are practically identical in the gravid female and the male except for the terminal claws of the antenna. The ventral claw is slender, consisting of a long narrow terminal portion attached to a very short, bulbous base. This claw has a length approximately equal to the length of the distal portion of the penultimate podomere of the antenna and bears ten to

twelve teeth. The slender, acutely pointed dorsal claw has a length equal to about four-fifths of the ventral claw. The teeth of the dorsal claw are so poorly developed that they can hardly be distinguished under the oil immersion lens using a 15x ocular. The medial claw, which is so short and slender that it can be observed only with difficulty, has a length but little more than that of the bulbous base of the ventral claw and appears edentate. The thoracic legs are very similar to those of the male except that both setae of the basal podomere of the legs of the first pair are relatively long, each reaching to the level of the seta of the antepenultimate podomere.

While no females were observed in copulation, a few individuals, possibly copulating females of this species, were observed. These are slightly smaller than the gravid females and males and the shell is more regularly oval in outline. The appendages show nearly the same general characteristics in the copulating female as in the gravid, the chief differences, with exception of the antenna, being in length:width ratios of podomeres. Each antenna has two end claws and the penultimate podomere of the antenna is undivided. The two setae of the pair on the flexor surface of the penultimate podomere of the antenna are very unequal, one being little more than a spine.

Distribution and Ecology.—Known only from the type locality.

Remarks.—The relatively small size and the rudimentary talon of this species indicate a relationship of this form to Entocythere species in which a talon is well developed (group *heterodonta* Rioja 1944). As a result of the small talon found in some individuals of *E. heterodonta* Rioja 1940 (*vid.* Rioja, 1940, plate 3, fig. 8), it is possible that this species is the closest relative of *E. talulus*. The two may be separated by the presence in *E. talulus* of five rather than four distal setae on the antennule, the fusion of the proximal three podomeres of the mandibular palp in *E. talulus*, as well as by the much longer distal setae of the protopodite and greater number of setae in the respiratory plate of the maxilla.

Entocythere hobbsi sp. nov.

Figs. 26-33

This very common and frequently occurring species has been named in honor of Dr. Horton H. Hobbs, Jr., of the University of Florida. Holotype (male), allotype (gravid female), and paratypes (both sexes), U. S. N. M.

Male.—The shell (Figs. 26 and 27) of the male is roughly oval in shape with the greatest height near the midpoint of the dorsal margin. The anterior slope of the dorsal margin forms a long and evenly curved arc while the posterior slope is very abrupt and often forms a slight angulation at the juncture with the posterior margin. The ventral margin is nearly straight, sometimes very slightly concave in the center. In most individuals, a slight break in the arc marks the juncture of the dorsal and the anterior margins. The left valve is considerably higher than the right. The circular eye is placed at a point about one-fourth of the distance from the anterior end of the shell. The shell displays dorsal pigmented areas in the majority of specimens and in some

individuals pigment spots may be found scattered in the ventral shell half. In general, the shape and pigmentation of the shell is extremely variable. The shell sizes of several males mounted in clarite are as follows:

Length	Height	
0.39 mm.	0.24 mm.	(holotype)
0.40	0.25	(paratype)
0.38	0.23	(paratype)
0.34	0.21	(Hampton Co., So. Car.)
0.35	0.21	(Clinch Co., Ga.)

Each antennule is composed of six podomeres of nearly equal length except that the first is longer and the third is shorter than any of the others. The first and second podomeres each bear distally one seta; the third podomere supports two setae; the fourth bears six setae, one group of three roughly medial and the other group of three nearly on the extensor surface. Setae are wanting on the fifth or penultimate podomere while the terminal podomere supports four long and one shortened setae. The antepenultimate podomere of the antenna is one and one-half times as long as wide and bears on the flexor-distal corner a stout feathered seta which extends beyond the end of the proximal portion of the penultimate podomere. The penultimate podomere of the antenna is divided into basal and distal portions. The basal portion of the penultimate podomere bears on the distal-flexor corner a pair of subequal setae, the longer of which does not reach to the distal end of the distal portion of the podomere. The distal portion bears a seta which arises slightly terminal to the midpoint of that part of the podomere and reaches nearly to the tip of the medial terminal claw. Of the terminal claws of the antenna, the ventral one (Fig. 28) is slender and distally curved, with a length slightly longer than the length of the antepenultimate podomere of the antenna. This claw bears fine comb-like teeth along the distal two-thirds. The flattened distal portion of the dorsal claw bears eleven or twelve well developed teeth. The median claw reaches slightly beyond the proximal corner of the flattened portion of the dorsal claw and appears to have about fifteen teeth.

With respect to the mandible, the protopodite bears distally seven teeth, the smallest of which is unicuspid, the larger of which has five cusps, while the others appear to have three cusps each. Between the distal teeth and the base of the palp is a spine on the convex surface of the protopodite. The respiratory plate of the mandible is represented by three setae. The palp (Fig. 29) consists apparently of four podomeres but the second and third podomeres are so fused that no indication of a suture remains. The basal podomere bears on the distal-flexor corner a seta which reaches to the base of the terminal spine of the palp. The distal end of the penultimate podomere bears on the extensor corner a spine which reaches well beyond the base of the terminal claw of the palp and laterally, some distance removed from the distal end, a longer seta which reaches almost to the tip of the palpal claw. The ultimate podomere is cone-shaped and bears distally a pair of very slender setae above which is a large claw-like spine. This last is not terminally acute but retains considerable width to the end, being somewhat spatulate in shape. The slender setae have about the same length as the heavy spine.

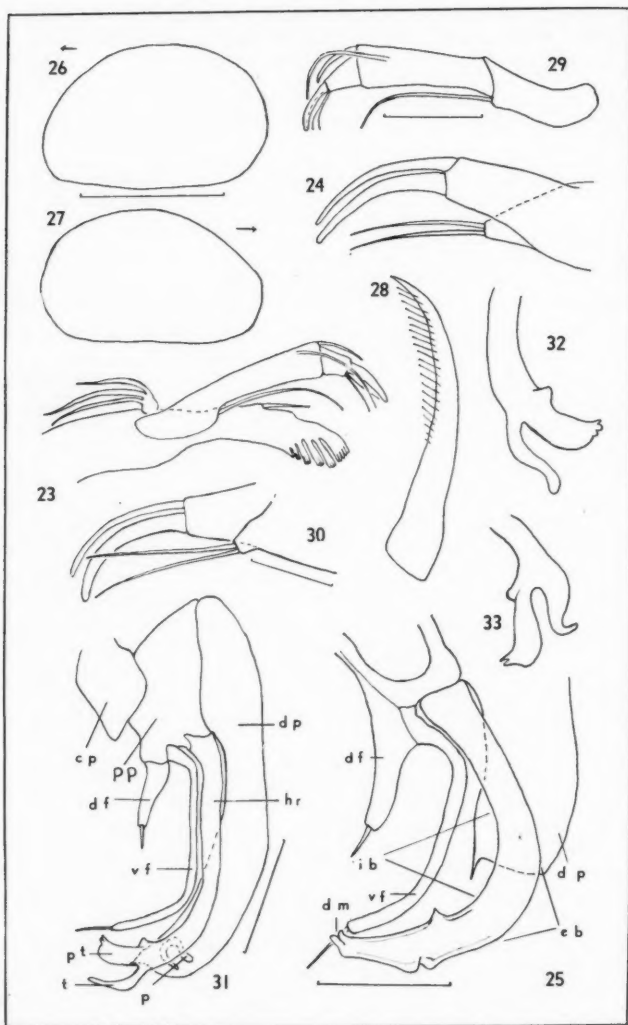


PLATE 3: Figs. 23-25. *Entocythere talulus* sp. nov. 23, Lateral view of mandible of male paratype. Scale as in Fig. 29. 24, Lateral view of palp and base of maxilla of male paratype. Scale as in Fig. 30. 25, Distal portion of copulatory complex of male holotype. Scale equals 0.025 mm. DF—dorsal finger, DM—distal margin, DP—distal portion of the base, EB—external border, IB—internal border, VF—ventral finger.

The maxilla has a respiratory plate containing eighteen setae. The palp (Fig. 30) has the podomeres fused together and ends terminally in a long curved spine, parallel to which, on the convex side, is a more slender spine subequal in length to the first. The protopodite does not extend fully to the end of the palp, being fleshy and bearing distally two long, very slightly curved setae. Like the maxilla the legs display no very striking features. The basal podomere in each of the first pair of legs bears distally and anteriorly two setae, one of which has a length much less than one-half of the other. The remaining legs have a single seta in this position. The antepenultimate podomere of each leg bears a spine on the anterior surface removed from the distal end by about the width of the podomere at the base of the spine. The distal-anterior corner of the penultimate podomere bears a single spine. The terminal claws are not unusual, each bears five or six teeth.

The most distinctive characteristics of the species are found in the copulatory structures (Fig. 31). The proximal portion of the base is relatively small, being subrectangular in shape with the distal portion attached along one side. The distal portion is elongated, slightly curved, and with the concave surface ending in an acute point. The dorsal finger is heavy and fleshy, and supports a spine having a length about one-third of the length of the finger. The ventral finger is long and slender and lies somewhat parallel to the clasping apparatus. The finger is curved near each end but the central portion is nearly straight. The clasping apparatus is somewhat bowed near the center of the long, vertical ramus, the inner margin being as a result slightly convex. The variable horizontal ramus (Figs. 31, 32, and 33) is relatively short and supports a very conspicuous, but apparently poorly chitinous talon. The talon extends at an acute angle from the external border of the ramus and then curves toward the distal end of the ramus. In some individuals, the very tip may be recurved away from the ramus. The somewhat swollen post-talon part of the ramus terminates in two or three small teeth. On the inner border of the horizontal ramus near the level of the talon is a single pyramid-shaped tooth.

Female.—The shell of the gravid female is practically identical with the shell of the male. Shells of several gravid females mounted in clarite measure as follows:

Length	Height	
0.40 mm.	0.25 mm.	(allotype)
0.40	0.25	(paratype)
0.43	0.26	(paratype)
0.42	0.26	(paratype)

Figs. 26-33. *Entocythere hobbsi* sp. nov. 26. Outline of the left valve of shell of male holotype. Scale equals 0.25 mm. 27. Outline of shell of a male paratype. Scale as in Fig. 26. 28. Ventral antennal claw of male holotype. Scale as in Fig. 30. 29. Palp of mandible in lateral view; male paratype. Scale equals 0.025 mm. 30. Medial view of palp and base of maxilla of male paratype. Scale equals 0.01 mm. 31. Copulatory complex of male paratype. Scale equals 0.05 mm. CP—connecting piece, DF—dorsal finger, DP—distal portion of the base, HR—vertical ramus, P—penis, PP—proximal portion of the base, PT—post-talon portion of horizontal ramus, T—talon, VF—ventral finger. 32. End of clasping apparatus of male holotype. Scale as in Fig. 29. 33. End of clasping apparatus of a second male paratype. Scale as in Fig. 29.

The appendages, except for those ordinarily showing sexual dimorphism, are nearly identical in the gravid female and the male. In the former, the setae of the two portions of the penultimate podomere appear to be slightly longer than in the male, those of the pair on the basal portion reaching to about the level of the end of the distal portion of the penultimate podomere while the seta of the distal portion reaches to the level of the medial terminal claw of the antenna. The terminally curved ventral claw has a length nearly equal to the length of the penultimate podomere of the antenna. This claw bears about eighteen conspicuous and well developed teeth. The dorsal claw is more slender, less curved, not so long, and has very fine teeth along the distal two-thirds. The medial claw, which is about one-third the length of the ventral claw, is exceedingly slender and very easily overlooked. The setae of the pair on the basal podomere of the first pair of legs are longer and more nearly equal in length in the female than in the male.

The copulating female has the penultimate podomere of the antenna undivided and has only two terminal claws. The shell is more regularly oval with the dorsal arch not so high as in the shell of the gravid female. Several shells of females taken in copulation and mounted in clarite measure as follows:

Length	Height	
0.35 mm.	0.21 mm.	(paratype)
0.33	0.20	(Colquitt Co., Ga.)
0.34	0.21	(Colquitt Co., Ga.)

Distribution and Ecology.—The holotype, allotype, and some paratypes were taken from crayfish of the species *Procambarus advena* secured from burrows near Fitzgerald, Ben Hill Co., Georgia, on April 14, 1939, while other paratypes were taken from *P. alleni* collected in a roadside ditch near Orlando, Orange Co., Florida, on Nov. 11, 1938. Other localities from which this form was secured were widely scattered in Florida and Georgia except for a single collection (on *P. lunzi*) from Hampton Co., South Carolina. Besides the crayfishes from which type specimens were taken, collections were secured from the following species: *P. advena* (3), *P. alleni* (2), *P. seminolae* (2), *P. barbatus* (2), *P. blandingii acutus* (1), *P. hubbelli* (2), *P. kilbyi* (1), *P. leonensis* (1), *P. lunzi* (1), *P. paeninsulanus* (1), *P. pictus* (1), *P. pubescens* (1), and species undetermined (2). The number after each crayfish species indicates the number of collections of that species from which *Entocythere hobbsi* was secured. All evidence for host specificity in this species is lacking.

Remarks.—*E. hobbsi*, by its possession of a talon on the clasping apparatus of the male copulatory complex, is evidently related to other talon-bearing forms (group *heterodonta* Rioja 1944) of the genus: *E. heterodonta* Rioja 1940, *E. copiosa* Hoff 1942, *E. sinuosa* Rioja 1942, and possibly *E. talulus* sp. nov. The closest relationship, however, probably exists with *E. copiosa* as indicated by the nearly equal shell size, the same number of setae on the maxillary respiratory plate, and the long vertical ramus of the clasping apparatus in the two species. Differences in shell shape and the length and shape of the talon make possible separation of the two forms.

Summary

1. A general discussion is given of the relative value of certain structures used in characterization of the genus *Entocythere* and the included species.
2. Subgenera based on the number of end claws in the antenna are considered inadvisable.
3. The structure of the male copulatory complex is outlined.
4. Six new species of *Entocythere*, one from Illinois and five from the extreme southeastern United States, are described.

REFERENCES

- DOBBIN, CATHERINE N. 1941—Fresh-water Ostracoda from Washington and other western localities. Univ. Wash. Pub. Biol. 4:174-246.
- HOFF, C. CLAYTON. 1942—The subfamily Entocytherinae, a new subfamily of fresh-water cytherid Ostracoda, with descriptions of two new species of the genus *Entocythere*. Amer. Mid. Nat. 27:63-73.
- 1943—Two new ostracods of the genus *Entocythere* and records of previously described species. Jour. Wash. Acad. Sci. 33:276-286.
- KLIE, W. 1931—Campagne spéologique de C. Bolivar et R. Jeannel dans l'Amérique du Nord (1928). 3. Crustacés ostracodes. Arch. Zool. exp. gén. 71:333-344.
- MARSHALL, WM. S. 1903—*Entocythere cambaria* (nov. gen. et nov. spec.), a parasitic ostracod. Trans. Wisconsin Ac. Sci. 14:117-144.
- RIOJA, ENRIQUE. 1940—Morfología de un ostrácodo epizoario observado sobre *Cambarus* (*Cambarellus*) *montezumae* Sauss. de México, *Entocythere heterodonta* n. sp. y descripción de algunos de sus estados larvarios. Anal. Inst. Biol., México 11:593-609.
- 1942a—Descripción de una especie y una subespecie nuevas del género *Entocythere* Marshall, procedentes de la Cueva Chica (San Luis Potosí, México). Ciencia 3:201-204.
- 1942b—Consideraciones y datos acerca del género *Entocythere* (Crust. Ostrácodos) y algunas de sus especies, con descripción de una nueva. Anal. Inst. Biol., México 13:685-697.
- 1944—Nuevos datos acerca de los *Entocythere* (Crus. ostrácodos) de México. Anal. Inst. Biol., México 15: [In press].
- SARS, G. O. 1926—Freshwater Ostracoda from Canada and Alaska. Rept. Canadian Arctic Exp., 1913-1918 7:1-22.

QUINCY COLLEGE,
QUINCY, ILL.

Helminths of Minnesota Canidae in Relation to Food Habits, and a Host List and Key to the Species Reported from North America¹

Arnold B. Erickson

Introduction

The parasitological examination of various species of wild North American Canidae has been limited until recently to a few animals or has been incidental to other investigations such as food habits studies. Much of the information pertaining to parasites of this group of host species has resulted from the investigations carried on in the interest of fur farmers. Some additional parasitological data have been obtained by the examinations of wolves, coyotes, and foxes in zoological gradens. The present report is based on the necropsy findings for 287 Canidae of four species. The known worm parasites of North American Canidae have been listed under their hosts, and a key for their determination has been appended.

Stiles and Baker (1935) in "Key Catalogue of Parasites Reported for Carnivora (cats, dogs, bears, etc.)" listed the known parasites of these hosts together with the literature pertaining to them. Their manuscript was submitted for publication August 26, 1931. For this reason, a review of the literature of helminths of North American Canidae must go back to about 1930.

Review of Literature

Kingscote (1930) reported *Paragonimus* from a ranch fox in Ontario, stating that the specimens had been sent to M. C. Hall for identification.

Chitwood (1931) reported *Physaloptera praeputialis* from the gray fox *Urocyon* sp. in Virginia. The host was undoubtedly the species *cinereoargenteus*, the only species recognized from eastern United States. In 1933, Chitwood reported the guinea worm (*Dracunculus medinensis*) from silver foxes (*Vulpes fulva*) in Iowa, New York, and Ontario. The nematode (*Passalurus nonanulatus*) was described from snowshoe hares and coyotes by Skinker in 1931, who considers the species a spurious parasite of coyotes. In 1932, Skinker reported the nematode *Molineus patens* from a coyote in Washington, and in 1935, she recorded *Taenia laticollis* from the same host. La Rue and Barone (1932) described *Alaria oregonensis* from a coyote collected in Oregon, and in 1936 La Rue and Fallis described *Alaria canis* from a dog. *Alaria canis*, or a species very similar to *A. canis*, has been found by us in the red fox and coyote in Minnesota. Specimens have been submitted to Dr. La Rue for determination.

¹ Paper No. 2098 Scientific Journal Series Minnesota Agricultural Experiment Station, St. Paul. Prepared under the joint cooperation by the Division of Entomology and Economic Zoology, University of Minnesota, and the Pittman-Robertson Project 11-R, Minnesota Division of Game and Fish, Department of Conservation.

Law and Kennedy (1932) were among the first investigators to encourage trappers to submit carcasses of fur-bearing animals for parasitological examination. From wild-caught foxes taken in Ontario, they recovered the strigeid flukes *Alaria americana* and *A. arisaemoides*, and from wild-caught timber wolves, *A. americana* and *Taenia pisiformis*. In addition, they reported various species of nematodes and cestodes from ranch foxes.

Riley (1933, 1939a, 1939b) reported on the incidence of hydatids in moose and deer in Minnesota and of *Echinococcus granulosus* in timber wolves. Swales (1933) in a review of Canadian helminthology listed the various parasites that had been reported from wolves and foxes in Canada. The *Paragonimus* from the fox mentioned by Kingscote (1930) is given by Swales as *P. kellicotti*. Swales also listed *Dipylidium caninum* from the fox, apparently the first record for this host in North America. Allen (1934) published notes on various parasites of fur-bearing animals and their control, together with lists of parasites of these hosts. The only record of *Trichinella spiralis* in North American Canidae known to the writer is that of Parnell (1934) who reported the nematode from an arctic fox (*Alopex lagopus*) in northeast Canada. Olsen, Fenstermacher, and Pomeroy (1937) reported *Physaloptera felidis* from a coyote taken in Minnesota. Morgan (letter to the author, June, 1942) examined the worms reported on by Olsen, *et al.* and pronounced them to be the closely related *P. rara* rather than *P. felidis*, which was originally reported from cats by Ackert.

The first record of the heartworm (*Dirofilaria immitis*) in wolves in North America is that of Faust, 1937. He examined two wolves (*Canis rufus floridanus*) shot at Lake Pontchartrain, Louisiana, in 1930 which were heavily parasitized with this *Filaria*. Hartley (1938) reported on the pathology produced by *D. immitis* in a timber wolf that died in the New York Zoological Park. His article contains a very extensive bibliography of *D. immitis* infections.

Chitwood (1938) made a study of a number of lots of specimens of protospirurids from coyotes collected in six western states. His morphological findings of this material indicate that certain species included in the genus *Protophysalura* should be placed in a new genus. For these species he has revived the genus *Mastophorus* Diesing, 1853 which Seurat (1916) synonymized with the genus *Protophysalura*. *Protophysalura muris*, which Chitwood has divided into two varieties based on the size of the teeth, is one of the species assigned by him to the genus *Mastophorus*. *Mastophorus muris* var. *ascaroides* is the form that he has found in the coyote. This worm was originally described from the pocket gopher (*Geomys breviceps*) by Hall in 1916. Among those species that Chitwood has retained in the genus *Protophysalura* is *P. numidica*, which he found to occur commonly in the coyote.

Chaddock (1939) in a report on the food habits of foxes in Wisconsin stated that of 113 gray fox stomachs, roundworms were noted in 61, or 52 per cent, and of 20 red fox stomachs, they were noted in four, or 20 per cent. Although the author makes no statement concerning the identity of these worms, it is probable that most of them were *Physaloptera*. Unfortunately, the

worms were discarded. A new species of tapeworm (*Taenia laruei*) from a coyote collected in Oklahoma was described by Hamilton in 1940. In a preliminary study on parasites of upland game birds and fur-bearing animals in Illinois, Leigh (1940) listed the following helminths from wild-caught red foxes: *Echinoparyphium* sp., *Taenia pisiformis*, *Ancylostoma caninum*, *Toxocara canis*, and *Trichuris* sp. Morgan (1941) published a catalogue of the nematodes of the sub-family Physalopterinae. *Physaloptera felidis* which is listed as occurring in the gray foxes is, according to the author, an error (letter to the writer, June, 1941). Goble and Cook (1941) reported on examinations of the lungs of 40 red and 12 gray foxes. The animals were trapped in New York State. *Eucoleus aerophilus* occurred in the lungs and trachea of 22 of the red foxes and *Crenosoma vulpis* occurred in the bronchi of six and two gray foxes. Sperry (1941) in an extensive account of the food habits of the coyote reported the finding of the following helminths: *Taenia* sp., *Toxocara* sp., *Physaloptera* sp., *Protospirura numidica*, and *Mastophorus muris* var. *ascarioides*. The helminths were identified by B. G. Chitwood and Allen McIntosh of the U. S. Department of Agriculture.

Hobmaier (1941) experimentally infected silver fox pups with the lung-worm, *Crenosoma mephitidis*, which proved to be highly fatal. This species was described by Hobmaier in 1941 from skunks in California. MacGregor (1942) in a study of food habits of foxes in Massachusetts reported that worms were found in 12 out of 13 gray fox stomachs and in one gray fox dropping. The worms were identified by Dr. J. F. Mueller, of the New York State College of Forestry, as follows: *Toxascaris limbata*? [= *leonina*], *Physaloptera* sp., *Taenia pisiformis*?, and *Taenia* sp.

Goble (1942) examined 184 adult wild-caught red foxes and 88 adult wild-caught gray foxes taken in New York State. Twenty-one or 39 per cent of the red foxes and 15 or 17 per cent of the gray foxes were infected by *Crenosoma vulpis*. Sixty-six or 36 per cent of the red foxes and 6 or 7 per cent of the gray foxes were infected by *Capillaria aerophila*. Through the courtesy of Dr. Goble the writer is permitted to list the first definite record of the heartworm (*Dirofilaria immitis*) from a red fox. The host, taken in Greene County, New York, in 1941, was examined by Dr. Goble who recovered the worm. There is another record of *D. immitis* in a fox. In the discussion following a paper by Hall (1926) Cobb mentioned having found *D. immitis* in a "wild fox" in Massachusetts. No species was indicated.

Smith (1943) reported on the examination of 234 red foxes collected in Iowa. Of these animals, 140 were parasitized by *Toxascaris leonina*, 80 by *Physaloptera felidis*, and 21 by *Toxocara canis*. Other nematodes recovered were *Ancylostoma caninum*, *Cruzeia* sp., and *Trichostrongylinae*. The last two are considered accidental parasites. Two undetermined species of *Taenia*, a species of *Mesocestoides*, and *Cittotaenia pectinata* were also found in the foxes. *C. pectinata* is a tapeworm of rabbits; its occurrence in the fox must have resulted from ingestion of a parasitized rabbit.

Buechner (1944) reported on the examination of 104 gray foxes collected in Texas from which he recovered ten species of helminths.

Source of Material

The Canidae on which this report is based were collected in the wild in Minnesota from 1932 to 1944. They represent four species as follows: Timber wolf (*Canis nubilus*), 27 specimens of which nine were represented by stomachs only; coyote (*Canis latrans*), 65 specimens of which four were represented by stomachs only; gray fox (*Urocyon cinereoargenteus*), 43 specimens of which 12 were represented by stomachs only and five by intestines only; and red fox (*Vulpes fulva*), 152 specimens of which 32 were represented by stomachs only. Most of the animals had been skinned but otherwise were entire except as noted above.

Most of the timber wolves were taken in two areas in northern Minnesota—the counties north of Lake Superior and the region between Red Lake and Lake of the Woods. Although the majority of the coyotes were collected in northern Minnesota in Lake of the Woods and St. Louis Counties, a few were trapped or shot in the northeastern, southeastern, and western parts of the state. All but six of the gray foxes originated from the southeastern corner of the state. The red foxes were collected in all parts of the state. The animals were obtained through the cooperation of Mr. J. Manweiler, Mr. J. Laughy, Dr. W. J. Breckenridge, Mr. Karl Kobes, Mr. H. A. Stiehm, Mr. B. A. Nelson, and various state game wardens.

Parasites Recovered from the Hosts

Twenty-three species of helminths were recovered from the 287 wolves, coyotes and foxes examined. The percentage of hosts infected by each species of parasite is based on the parts of the host that were available for study. In some cases, because of the condition of the material, it was not possible to determine the species of parasites. The data are summarized in Table No. 1.

Food Habits of Canidae as Reflected by Tapeworms

The adult tapeworms found during this study, all of which require intermediate hosts for the immature stages, reflect to a degree the food habits of the Canidae and the availability of various food species. *Echinococcus granulosus*, for example, occurred in timber wolves, and only in those wolves obtained in the counties north of Lake Superior where 36 per cent of the moose examined by Olsen and Fenstermacher (1942) harbored hydatid cysts.

The larval stage of *Taenia hydatigena* occurs in the muscles and liver of deer and other ruminants.² The fact that 44.4 per cent of the wolves and 31.1 per cent of the coyotes were infected by the adult form of the tapeworm is

² In examining these wolves and coyotes for parasites, I have opened the stomachs to search for stomach worms and have had ample opportunity to note that deer meat and hair occurred in many stomachs. The stomach contents have been preserved for complete analysis later.

Further information on the deer-feeding habit of wolves in the Superior National Forest, Minnesota, is given in a paper by Olson, Sigurd F. 1938—A study in predatory relationship with particular reference to the wolf. Sci. Mon. 46:323-336.

TABLE 1.—Helminth Parasites Recovered from 287 Wolves, Coyotes, and Foxes. Percentages are Based on the Parts Available for Study.

Name of Parasite	H O S T S			
	Canis lupus % infected	Canis latrans % infected	Urocyon cinereoargenteus % infected	Vulpes fulva % infected
Trematodes or flukes				
<i>Alaria canis</i>	0.0	0.0	12.9	0.83
<i>Alaria mustelae</i>	0.0	1.6	0.0	0.0
<i>Paragonimus kellicottii</i>	0.0	0.0	0.0	0.83
Cestodes or tapeworms				
<i>Echinococcus granulosus</i>	27.7	0.0	0.0	0.0
<i>Multiceps packii</i>	5.5	1.6	3.2	0.0
<i>Multiceps serialis</i>	0.0	0.0	0.0	1.6
<i>Multiceps</i> sp.	0.0	11.4	0.0	1.6
<i>Taenia hydatigena</i>	44.4	31.1	0.0	0.0
<i>Taenia krabbei</i>	0.0	3.2	0.0	0.0
<i>Taenia pisiformis</i>	27.7	39.3	58.0	5.0
<i>Taenia rileyi</i>	0.0	4.9	0.0	0.0
<i>Taenia</i> sp.	5.5	4.9	12.9	0.83
Nematodes or roundworms				
<i>Ancylostoma caninum</i>	0.0	3.2	0.0	0.0
Ascarinae	0.0	0.0	0.0	6.6
<i>Dioclophyma renale</i>	5.5	0.0	0.0	0.0
<i>Filaroides osleri</i>	5.5	5.6	0.0	0.0
<i>Physaloptera rara</i>	0.0	4.6	34.2	13.1
<i>Physaloptera</i> sp.	3.7	12.3	47.3	9.2
Strongyle	0.0	0.0	0.0	0.83
<i>Toxascaris leonina</i>	0.0	0.0	0.0	67.5
<i>Toxocara canis</i>	0.0	0.0	0.0	3.3
<i>Trichostrongylus</i> sp.	0.0	0.0	0.0	0.83
<i>Uncinaria stenocephala</i>	27.7	0.0	0.0	1.6

further evidence that deer meat forms a substantial part of their diet. That deer meat is seldom available to foxes, both because of the comparative scarcity of deer in much of their habitat and because of their inability to take large game, is shown by the fact that *T. hydatigena* was not found in these hosts. *Taenia pisiformis* and *Taenia* sp. (probably *pisiformis*), on the other hand, occurred in 70.9 per cent of the gray and 5.8 per cent of the red foxes, indicating that they had been feeding on rabbits infected by the larval stages. That rabbits form an important part of the food of wolves and coyotes is evidenced by the fact that 27.7 per cent of the wolves and 39.3 per cent of the coyotes examined contained *T. pisiformis*. The incidence of *Multiceps packii* and *M. serialis* in hares and rabbits in Minnesota is probably much lower than the incidence of *T. pisiformis*. This is indicated by the fact that only a small percentage of the Canidae examined harbored the adult forms of these tapeworms. Extensive examinations of hares and rabbits have shown, likewise, that the larval stage of *T. pisiformis* is much more common than larvae of the genus *Multiceps*.

In Minnesota *Taenia rileyi* occurs regularly in the bobcat (*Lynx rufus*). But we have found it only three times in Canidae—in coyotes taken in St.

Louis and Itasca counties. The intermediate host of this tapeworm is unknown but is possibly a mouse.

Trematodes of the genus *Alaria* occurred in only a small percentage of the hosts examined. One coyote was parasitized by *A. mustelae*?, the metacercarial stage of which occurs in frogs and occasionally in the meadow mouse which serves as a transport host. About 13 per cent of the gray and 0.8 per cent of the red foxes harbored *A. canis*?. The intermediate hosts of this species are unknown, but it is probable that some small mammal may serve as a transport host for the metacercariae.

Thirty-one *Paragonimus kellicotti*, a lung fluke of carnivores, were recovered from a red fox collected near Redwood Falls, in February, 1944. Although it occurs commonly in minks, this is the first record of its occurrence in a wild red fox in North America. The primary hosts of *P. kellicotti* become infected by eating crayfish which harbor the metacercarial stage.

The stomach worms *Physaloptera rara* and *Physaloptera* sp. (probably *rara*) occurred in 3.7 of the wolves, 16.9 per cent of the coyotes, 81.5 per cent of the gray foxes, and 22.3 per cent of the red foxes. Roundworms of the genus *Physaloptera* are thought to pass the larval stage encysted in insects; however, larvae have been found in the muscles of ruffed grouse (*Bonasa umbellus*) and Bonaparte weasels (*Mustela cicognanii*) in Minnesota. According to several authors (Sperry, 1941; Chaddock, 1939) insects, especially grasshoppers and beetles, are regularly eaten by coyotes and foxes. Hatfield (1939), who reported on the food habits of the foxes which the present writer examined for parasites, found only a trace of insect remains, probably not enough to account for the frequent infections by *Physaloptera*. It seems possible that, in addition to becoming parasitized by *Physaloptera* through the eating of infected insects, coyotes and foxes also become infected by eating various small mammals and birds which may serve as transport hosts for *Physaloptera* larvae. The hookworm (*Ancylostoma caninum*) was found only in coyotes; 3.2 per cent were parasitized. The hookworm (*Uncinaria stenocephala*) occurred in 27.7 per cent of the timber wolves and 1.6 per cent of the red foxes. The ascarid nematode (*Toxascaris leonina*) occurred in 67.5 per cent of the red foxes.

Concurrent infections were common. Eight wolves, 18 coyotes, 30 red foxes, and 17 gray foxes harbored two or more species of helminths.

The Effect of Parasites on the Hosts

Little information was obtained on the effect of the various parasites on their hosts. The intestines of many of the wolves, however, contained so many large *Taenia hydatigena* that the intestines appeared to be partially occluded. The kidney of a wolf which had a giant kidney worm (*Dioctophyma renale*) in the body cavity was enlarged and appeared to be infected. Another wolf and three coyotes were parasitized by tracheal nematodes that occurred in cysts. Some of the cysts were small and contained only two worms each, but others were large (six to ten millimeters in diameter) and projected into the lumen

of the trachea and were covered by a sheet of connective tissue. The worms were digested out with hydrochloric acid and pepsin. They are so fragmentary, however, that it has been impossible to identify them, although it is possible that they are *Filaroides osleri*. All of the worms are females, and all contain many embryos.

The lungs of the red fox infected with *Paragonimus kellicotti* showed externally many enlarged discolored areas. The flukes occurred in pockets in the bronchi and bronchioles, usually two to four per pocket. Considerable pus and mucus were present.

Relation of Parasitism in Wild Canidae to Ranch Animals

It has been shown again and again that wild animals do act as reservoirs for and transmitters of parasites to man and domestic animals. This is true of wild Canidae as it is true of other groups of animals. The helminths of Canidae which require intermediate hosts are those which are most apt to be transferred to captive fur-bearing animals.

Among this group are the tapeworms *T. pisiformis*, *M. serialis*, and *M. packii*, whose larval stages occur in hares and rabbits. Each year tons of rabbit carcasses are sold to fur farmers for fox and mink foods. Unless good cold storage facilities are available, the chances for introducing these parasites to ranch animals are excellent. Likewise, there is danger of infection from the tapeworms *T. hydatigena* and *T. krabbei* which pass the larval stage in the muscles of cattle, deer, and other ruminants.

E. granulosus occurs in wolves and moose in endemic areas such as north-eastern Minnesota. Cattle, sheep, and horses pasturing in woodlands of such regions are in danger of picking up the eggs of *E. granulosus* which have been passed out with the feces of wolves. The hydatid, or larval stage, may occur in any of the above animals which are frequently used as fox food. Infected foxes would be a constant source of danger to man and other animals. Stomach worms of the genus *Physaloptera* are believed to require insects for their larval stages, and the lungworm *Crenosoma vulpis* is known to pass the larval stage in various beetles. Living in the vicinity of fur farms, wild animals infected by these parasites would be a source of danger to captive animals through the various insects which would have the opportunity to feed on eggs passed out with the feces of the infected Canidae, and thus become parasitized by the intermediate stages. Ranch animals eating these infected insects, either intentionally or accidentally, would become infected by the adult forms of the parasites.

ACKNOWLEDGMENTS

I wish to thank Dr. W. A. Riley, Chief of the Division of Entomology and Economic Zoology, University of Minnesota, for suggestions and advice in preparing the manuscript and for his constant efforts, over the years, to obtain animals for parasitological study. I also wish to thank Dr. B. B. Morgan for identifying the *Physaloptera* and for suggestions on the best means of keying out the two species of this genus known to infect wolves, coyotes, and foxes.

Helminths Reported from North American Canidae

COYOTE—*Canis latrans*—and related forms.

Trematodes or flukes.

** *Alaria mustelae*? Bosma, 1931.* *Alaria oregonensis* La Rue and Barone, 1932 (19)³* *Amphimerus pseudofelineus*⁴ (Ward, 1895) Baker, 1911* *Trogloctrema* [= *Nanophyetus salmincola*] (Chapin, 1926) Witenberg, 1932

Cestodes or tapeworms.

* *Mesocestoides kirbyi* Chandler, 1944 (5a)* *Multiceps multiceps* (Leske, 1780) Hall, 1910** *Multiceps pachii* Christenson, 1929** *Multiceps* sp.** *Taenia hydatigena* Pallas, 1766** *Taenia krabbei* Moniez, 1879* *Taenia laruei* Hamilton, 1940 (13)* *Taenia laticollis* Rudolphi, 1819 (35)** *Taenia pisiformis* (Bloch, 1780) Gmelin, 1790** *Taenia rileyi* Loewen, 1929 (23a)*Taenia* sp.* *Taenia* sp. (37)

Nematodes or roundworms.

* *Ancylostoma caninum* (Ercolani, 1859) Hall, 1913** *Ancylostoma caninum*** *Dioclophyma renale* (Goeze, 1782) Balbiani, 1869 (29)** *Filaroides* [= *Oslerus*] *osleri*? (Cobbold, 1879) Skrjabin, 1933* *Mastophorus* [= *Protospirura*] *muris* var. *ascaroides* Chitwood, 1938 (8, 37)* *Molineus patens* (Dujardin, 1844) Skrjabin and Schulz, 1926 (34)* *Passalurus nonnulatus* Skinker, 1931 (33) (accidental)* *Physaloptera rara* Hall and Wigdor, 1918 (25, 26)* *Physaloptera* sp. (37)* *Protospirura numidica* Seurat, 1914 (8, 37)* *Rictularia splendida* Hall, 1913* *Toxascaris leonina* (Linstow, 1902) Railliet and Henry, 1911* *Toxascaris* sp. (37)* *Toxocara* sp.* *Toxocara* sp. (37)

Acanthocephala or thorny-headed worms.

* *Oncicola canis* (Kaupp, 1909) Travassos, 1916TIMBER WOLF—*Canis lupus*

Trematodes or flukes.

* *Alaria americana* Hall and Wigdor, 1918 (22)

Cestodes or tapeworms.

* *Echinococcus granulosus* (Batsch, 1786) Rudolphi, 1805 (30, 31, 32)** *Multiceps pachii* Christenson, 1929** *Taenia hydatigena* Pallas, 1766*** *Taenia pisiformis* (Bloch, 1780) Gmelin, 1790 (22)

Nematodes or roundworms

* *Ancylostoma caninum* (Ercolani, 1859) Hall, 1913** *Dioclophyma renale* (Goeze, 1782) Balbiani, 1869* *Dirofilaria immitis* (Leidy, 1856) Railliet and Henry, 1911 (15). Also reported from *C. rufus floridanus*, (9)

** New Record, See the Present Paper

* Recorded by various authors since Stiles and Baker (1935).

³ Numbers in parenthesis refer to authors in the bibliography who reported the parasite from the host in question.⁴ Species not marked by asterisks recorded by Stiles and Baker and include records up to about 1930.

- ** *Filaroides osleri*? (Cobbold, 1819) Skrjabin, 1933
- * *Physaloptera rara* Hall and Wigdor, 1918 (26)
- ** *Physaloptera* sp.
- Toxocara canis* (Werner, 1782) Johnston, 1916
- ** *Uncinaria stenocephala* (Railliet, 1884) Railliet, 1885

RED FOX—*Vulpes fulva*—and related forms.

Trematodes or flukes.

- * *Alaria alata* (Goeze, 1782) Schrank, 1788 (38)
- * *Alaria americana* Hall and Wigdor, 1918 (22, 38)
- Alaria arisaemoides* Augustine and Uribe, 1927
- ** *Alaria canis*? La Rue and Fallis, 1936
- Cryptocotyle lingua* (Creplin, 1825) Luhe, 1899
- Echinocasmus* sp.
- * *Echinoparyphium* sp. (23)
- Opisthorchis conjunctus* (Cobbold, 1860) Blanchard, 1895
- * *Paragonimus kellicotti* Ward, 1908 (18, 38)
- Parametorchis intermedius* Price, 1929
- Phagicola* [= *Parascocotyle*] *longa* (Ransom, 1920) Price, 1932
- Pseudamphistomum truncatum* (Rudolphi, 1819) Lühe, 1908
- Troglotherma salmincola* (Chapin, 1926) Whittenberg, 1932
- * *Sellacotyle mustelae* Wallace, 1934 (40) (Accidental)

Cestodes or tapeworms.

- * *Cittotaenia pectinata* (Goeze, 1782) (36) (Accidental)
- * *Diphyllbothrium cordatum* (Leuckart, 1863) Faust, 1929 (22)
- * *Diphyllbothrium latum* (Linné, 1758) Lühe, 1910 (22)
- Diphyllbothrium latum* (In *Vulpes* sp.)
- * *Dipylidium caninum* (Linné, 1758) Leuckart, 1863 (39)
- * *Mesocostoides* sp. (36)
- ** *Multiceps serialis* (Gervais, 1847) Stiles and Stevenson, 1905
- ** *Taenia pisiformis* (Bloch, 1780) Gmelin, 1790 (23)
- * *Taenia* sp. (36)

Nematodes or roundworms.

- * *Ancylostoma caninum* (Ercolani, 1859) Hall, 1913 (2, 4, 23, 36, 38).
- ** Ascarinae
- Capillaria* [= *Eucoleus*] *aerophila* (Creplin, 1839) Travassos, 1915
- * *Capillaria aerophila* (11, 12)
- Capillaria plica* (Rudolphi, 1819) Railliet, 1915
- * *Crenosoma mephitis* Hobmaier, 1941 (17)
- * *Crenosoma vulpis* (Dujardin, 1844) Schwartz, 1926 (11, 12, 22, 38)
- * *Cruzia* sp. (36) (Accidental)
- Diocotophya renale* (Goeze, 1782) Balbiani, 1869
- * *Diocotophya renale* (39)
- * *Dirofilaria immitis* (Leidy, 1856) Railliet and Henry, 1911 (10)
- * *Dracunculus medinensis*⁵ (Linné, 1758) Gallandant, 1773 (3, 7)
- * *Physaloptera felidis*⁶ Ackert, 1936 (26, 36)
- * *Physaloptera praeputialis* Linstow, 1889 (26)
- *** *Physaloptera rara* Hall and Wigdor, 1918 (26)
- ** *Strongyle* sp.
- *** *Toxascaris leonina* (Linstow, 1902) Railliet and Henry, 1911 (36)
- *** *Toxocara canis* (Werner, 1782) Johnston, 1916 (36)
- Toxocara cali* (Schrank, 1788) Brumpt, 1927
- * *Trichostrongylinae* (36) (Accidental)
- ** *Trichostrongylus* sp.
- Trichuris vulpis* (Froelich, 1789) Smith, 1908
- * *Trichuris* sp. (23)

⁵ Chandler (1942) tends to consider the *Dracunculus* reported from North American mammals as a species separate from the old world *medinensis*.

⁶ Morgan (in press) considers *P. felidis* a synonym of *P. rara*.

- Uncinaria stenocephala* (Railliet, 1884) Railliet, 1885
 *** *Uncinaria stenocephala* (38)
Uncinaria sp.
- KIT FOX—*Vulpes velox*
 Nematodes or roundworms.
Ancylostoma caninum (Ercolani, 1859) Hiall, 1913
Toxocara canis (Werner, 1782) Johnston, 1916
Uncinaria sp.
- GRAY FOX—*Urocyon cinereoargenteus*—and related forms.
 Trematodes or Flukes.
 ** *Alaria canis*? La Rue and Fallis, 1936
 Cestodes or tapeworms.
Diphyllobothrium latum (Leuckart, 1863) Lühe, 1910
 * *Mesocostoides litteratus* (Batsch, 1786) (4a)
Mesocostoides variabilis Mueller, 1927
 ** *Multiceps packii*? Christenson, 1929
 * *Multiceps serialis* (Gervais, 1847) Stiles and Stevenson, 1905 (4a)
Taenia pisiformis (Bloch, 1780) Gmelin, 1790
 ** *Taenia pisiformis*
 * *Taenia pisiformis*? (24)
 * *Taenia* sp. (24)
 Nematodes or roundworms.
Ancylostoma braziliense (Gomez de Favia, 1910) (4a)
Ancylostoma caninum (Ercolani, 1859) Hall, 1913
 * *Capillaria aerophila* (Creplin, 1839) Travassos, 1915 (4a, 12)
 * *Crenosoma vulpis* (Dujardin, 1844) Schwartz, 1926 (11)
 * *Haemonchis similis* Travassos, 1914 (4a) (Accidental)
 * *Physaloptera praeputialis* Linstow, 1889 (6, 26)
 *** *Physaloptera rara* Hall and Wigdor, 1918 (26)
 * *Physaloptera* sp. (24)
 * *Spirocerca lupi* (Rudolphi, 1809) Chitwood, 1933 (4a)
 * *Toxascaris leonina*? (24)
Toxocara canis (Werner, 1782) Johnston, 1916
Uncinaria sp.
- Acanthocephala or thorny-headed worms
 * *Pachysentis canicola* Mayer, 1931 (4a)
- ARCTIC FOX—*Alopex lagopus*
 Trematodes or flukes.
Apophallus donicum [=venustus] (Skrjabin and Lindtrop, 1919) Price, 1931
Phagicola longa (Ransom, 1920) Rice, 1932
Phagicola nana (Ransom, 1920) Price, 1932
Trogloctrema salmincola (Chapin, 1926) Witenberg, 1932
 Cestodes or tapeworms.
Mesocostoides lineatus (Goeze, 1782) Railliet, 1893
Mesocostoides sp.
Taenia sp.
 Nematodes or roundworms.
Toxocara canis (Werner, 1782) Johnston, 1916
 * *Trichinella spiralis* (Owen, 1835) Railliet, 1895 (28)
Uncinaria stenocephala (Railliet, 1884) Railliet, 1885

KEY TO THE TREMATODES OF NORTH AMERICAN CANIDAE

1. Body divided into a fore body and a hind body, the organs of attachment on
 on the fore body and the sex organs in the hind body 2
 Body not divided into two parts 7
2. No prominent ear-shaped projections on each side of the oral sucker.
 Total length 0.82 to 1.74 mm. *Alaria mustelae*
 Prominent ear-shaped projections present 3

3. Total length greater than 4.5 mm. Holdfast organ covering the pharynx and the oral sucker 4
- Total length less than 4.5 mm. Holdfast organ not covering the pharynx and the oral sucker 5
4. Total length up to 10.6 mm. The longitudinal ventral groove of the holdfast organ runs the length of the holdfast. Oral sucker 0.1 by 0.09 mm.; acetabulum 0.1 mm. in diameter; pharynx 0.15 by 0.13 mm. *Alaria arisaemoides*
- Total length up to 8.25 mm. The longitudinal ventral groove of the holdfast organ does not run the length of the holdfast. Oral sucker 0.074 to 0.095 mm. in length and 0.059 to 0.035 mm. in breadth; acetabulum 0.077 to 0.118 mm. in length and 0.062 to 0.099 mm. in breadth; pharynx 0.163 mm. in length by 0.126 to 0.178 mm. in breadth *Alaria oregonensis*
5. Anterior segment as wide as or wider than long; holdfast organ short partially covering the acetabulum whose diameter is greater than the distance separating its anterior margin from the point of bifurcation of the intestine.... *Alaria americana*
- Anterior segment oblong. Holdfast organ not covering the acetabulum whose diameter is much less than the distance separating its anterior margin from the point of bifurcation of the intestine..... 6
6. The anterior segment wider than the posterior segment. Vitelline glands ordinarily extend to the anterior margin of the holdfast organ, but sometimes to the level of the acetabulum. Ovary median..... *Alaria alata*
- The anterior segment narrower than the posterior segment. Vitelline glands extend to the level of the acetabulum. Ovary lateral or submedian..... *Alaria canis*
7. A collar of spines around the oral sucker. Testes tandem and parallel to length of body 8
- No collar of spines around the oral sucker, or if present, testes tandem and parallel to width of body 9
8. Head spines in a double row. Uterus short; eggs large..... *Echinoparyphium* sp.
- Head spines in a single row. Vitellaria reaching anterior to ovary.
- Sex glands midway from acetabulum to posterior end..... *Echinochasmus* sp.
9. In the bile ducts or liver 10
- In the intestines or lungs 13
10. Vitelline glands extending anterior of the acetabulum; loops of the uterus also extending anterior of the acetabulum *Parametorchis intermedius*
- Vitelline glands and loops of the uterus not extending anterior of the acetabulum.... 11
11. Vitellaria divided on each side into an antovarial and postovarial portion, the postovarial portion extending to near the posterior end. In the liver
- *Amphimerus pseudofelineus*
- Vitellaria not divided, not extending posterior to ovary 12
12. Uterus lying entirely between the intestinal ceca. Testes lobed
- *Opisthorchis conjunctus*
- Uterus overlapping the intestinal ceca more or less. Skin covered with fine spines
- *Pseudamphistomum truncatum*
13. Esophagus very short; testes usually beyond the middle of the body but some distance from the posterior end 14
- Esophagus long; testes situated near the posterior end 16
14. Intestinal ceca long, extending to near the posterior end 15
- Intestinal ceca short, extending slightly beyond the middle of the body. In the intestines *Troglorema salmicola*
15. Ventral sucker rudimentary and included in the genital sinus. In the intestines....
- *Cryptocotyle lingua*
- Ventral sucker not rudimentary and not included in the genital sinus. In the lungs *Paragonimus kellicotti*
16. Circumoral spines present
- Circumoral spines lacking *Apophallus donicum*
17. Oral cecum more than half the length of the prepharynx; circumoral spines 16 to 24 micra long *Phagicola longa*
- Oral cecum less than half the length of the prepharynx; circumoral spines less than 15 micra long *Phagicola nana*

KEY TO THE CESTODES OF NORTH AMERICAN CANIDAE

1. Scolex with two elongated, slit-like suckers 2
 Scolex with four rounded suckers 3
2. Scolex heart-shaped *Diphyllbothrium cordatum*
 Scolex lanceolate; uterus rosette-shaped *Diphyllbothrium latum*
3. Scolex without rostellum or hooks. Genital pores on ventral surface of segment, median 4
 Scolex with rostellum and hooks. Genital pores lateral; one or two in each segment 5
4. Testes 60 to 75 in number; egg capsule 0.45 to 0.50 mm. in diameter; eggs 40 to 60 by 35 to 43 micra *Mesocetoides lineatus*
 Testes 40 to 45 in number; egg capsule 0.35 to 0.40 mm. in diameter; eggs 22 micra in diameter *Mesocetoides variabilis*
 Testes 100 to 120 in number; egg capsule 0.45 to 0.56 mm. in diameter; gravid segments bell-shaped *Mesocetoides kirbyi*
5. Two genital pores in each segment *Dipylidium caninum*
 One genital pore in each segment 6
6. Worms short consisting of 3 to 5 segments *Echinococcus granulosus*
 Worms long consisting of many segments 7
7. Handle of large hook usually sinuous; vagina usually shows a reflexed loop in the vicinity of the longitudinal excretory canal 8
 Handle of large hook usually not sinuous; vagina without a reflexed loop 10
8. Mature segments wider than long; lateral margins scalloped by transverse furrows, posterior margin fitting glove-like over following segment. Genital papillae narrowly conical and near posterior margin of segment *Multiceps serialis*
 Mature segments longer than broad; lateral margins not marked by transverse furrows 9
9. Ovaries uniformly of same size. Testes do not extend posteriorly of ovaries to vicinity of vitellarium or between vitellarium and ovaries *Multiceps multiceps*
 Ovary on side opposite genital pore uniformly larger. Testes extending posteriorly as far as vitellarium *Multiceps packii*
10. Large hooks not over 220 micra long; scolex generally not more than 1 mm. in diameter 11
 Large hooks 225 micra long or longer; scolex generally more than 1 mm. in diameter 13
11. Large hooks 125 micra long; scolex about 690 micra in diameter *Taenia laruei*
 Large hooks more than 125 micra long 12
12. Large hooks 148 to 170 micra long; scolex about 640 micra in diameter *Taenia krabbei*
 Large hooks 170 to 220 micra long; scolex about 1 mm. in diameter *Taenia hydatigena*
13. Large hooks 225 to 294 micra long; scolex about 1.3 mm. in diameter *Taenia pisiformis*
 Large hooks 340 micra long or longer 14
14. Large hooks 340 to 386 micra long; 30 to 32 in number. Neck present; scolex 0.7 to 1.2 mm. in diameter *Taenia rileyi*
 Large hooks 380 to 420 micra long; 38 to 60 in number. No neck; scolex about 1.5 mm. in diameter *Taenia laticollis*

KEY TO NEMATODES OF NORTH AMERICAN CANIDAE

1. Adult worms parasitic in the intestinal tract and in various organs 2
 Larval worms encysted in the voluntary muscles *Trichinella spiralis*
2. Esophagus consisting of a narrow tube running through the center of a row of single cells for most of its length 3
 Esophagus not consisting of a narrow tube running through the center of a row of single cells 6

3. Worms fairly large, readily visible to naked eye, oviparous 4
 Worms small, just visible to naked eye, viviparous, parasitic in the intestine.....*Trichinella spiralis*
4. Anterior part of body longer than posterior, which is much thicker, parasitic in the intestine.....*Trichuris vulpis*
 Anterior part of body shorter than or rarely equal to posterior, which is slightly thicker 5
5. Spicules present; parasitic in the bladder*Capillaria plica*
 Spicules absent or rudimentary; parasitic in the lungs.....*Capillaria aerophila*
6. Males with a bursa copulatrix (bursa may be rudimentary as in *Filaroides osleri* which occurs in nodules in the trachea and bronchi)..... 7
 Males without a bursa copulatrix.....13
7. Bursa copulatrix cuticular and supported by rays. Eggs usually thin-shelled..... 8
 Bursa copulatrix muscular and not supported by rays. Eggs thick-shelled and the surface covered with depressions. In the kidney or body cavity.....*Diectophyma renale*
8. Parasites of the alimentary canal..... 9
 Parasites of the respiratory system.....12
9. Filiform worms with the buccal capsule feebly developed or absent.....10
 Stout worms with the buccal capsule well developed. Oral aperture guarded by teeth or chitinous plates.....11
10. Head enlarged due to inflation of cephalic cuticle. Dorsal ray bifurcate, each branch tridigitate. Tail of female ends in a terminal spine.....*Molincus patens*
 Head not enlarged due to inflation of cephalic cuticle. Dorsal ray, each branch bidigitate. Tail of female not ending in terminal spine.....*Trichostrongylus* sp.
11. One pair of plate-like cutting organs and one pair of subventral lancets. Dorsal lobe of the bursa much smaller than the lateral lobes.....*Uncinaria stenocephala*
 Three pairs of tooth-like cutting organs.....*Ancylostoma caninum*
12. Bursa copulatrix well developed supported by typical rays. Cuticle armed along the anterior part of the body with a series of rings composed of minute spines*Crenosoma vulpis*
 and *Crenosoma mephitis*. (The two species are very similar. The gubernaculum of the male *C. vulpis* is said to be slender in lateral view while that of *C. mephitis*, thick in front and tapered behind in lateral view).
 Bursa copulatrix rudimentary consisting of a cuticular extension. Cuticle not armed by a series of rings composed of spines.....*Filaroides osleri*
13. Esophagus dilated posteriorly into a bulb which is separated from the rest of the esophagus by a constriction.....*Passalurus nonnulatus*
 Esophagus not dilated posteriorly into a bulb which is separated from rest of esophagus by a constriction14
14. Head with 3 large lobes or lips. Relatively stout worms.....15
 Head without 3 large lobes or lips, but with 2 lateral lips or lips absent.....17
15. Tail of male not probular; spicules not winged; egg shell smooth.....*Toxascaris leonia*
 Tail of male probular; spicules winged; egg shell with mosaic markings.....16
16. Cervical alae long and narrow diminishing gradually in width posteriorly. Spicules 0.75 to 1 mm. long. Eggs 75 to 80 micra in diameter.....*Toxocara canis*
 Cervical alae broad, increasing to a maximum width towards their posterior ends and then diminishing suddenly. Spicules 1.6 to 2 mm. long. Eggs 65 to 75 micra in diameter.....*Toxocara cati*
17. Head with two lateral lips. Chitinous buccal cavity usually present. Vulva in middle of body or posterior to it. Parasites of the alimentary canal.....18
 Head without lips. Vulva in the esophageal region. Parasites of the heart or of skeletal muscular tissue, especially that of the hind legs22
18. Cuticle armed with two longitudinal rows of spines on the ventral surface.....*Rictularia splendida*
 Cuticle not armed with two longitudinal rows of spines on the ventral surface.....19

19. With a cephalic collarette. Males with caudal alae not meeting ventrally in front of the cloaca. Vulva in front of the middle of the body.....20
Without a cephalic collarette. Lips large and distinctly trilobed with cuticle of inner surface thickened and tending to interlock with that of opposite lip.....21
20. With a prepuce-like sheath over the posterior end of body.....*Physaloptera praeputialis*
Without a prepuce-like sheath over the posterior end of body.....*Physaloptera rara*
21. Stoma laterally compressed; caudal papillae sessile; tail of the male relatively short; vulva posterior to middle of body.....*Protospirura numidica*
Stoma cylindrical; caudal papillae stalked; tail of the male relatively long; vulva anterior to middle of body.....*Mastophorus muris* var. *ascaroides*
22. Parasites of the heart.....*Dirofilaria immitis*
Parasites of the skeletal muscles, especially those of the hind legs.....*Dracunculus medinensis*
Parasites occurring in nodules or tumors in the stomach and esophagus.....*Spirocerca lupi*

KEY TO THE ACANTHOCEPHALA OF NORTH AMERICAN CANIDAE

1. Length 6 to 14 mm. Proboscis with 36 hooks.....*Onicola canis*
Length 15 to 26 mm. Proboscis with 72 hooks.....*Pachysentis canicola*

REFERENCES

1. ALLEN, J. A. 1934—Parasites of fur-bearing animals. Proc. 5th Pan-Pacific Sci. Cong.; 2981-2989.
2. BATT, H. E. 1926—A note on the prevalence of internal parasites in foxes. Rept. Ontario Vet. College 1925:30-32.
3. BENBROOK, E. A. 1932—*Dracunculus medinensis* (Linnaeus, 1758) appears in the United States as a parasite of the fox. Jour. Am. Vet. Med. Assoc. 81:821-824.
4. BRUCE, E. A. 1930—Report of Veterinary Director General, Dom. Dept. of Agric. for year ending March 31, 1930; 41.
- 4a. BUECHNER, HELMUT KARL. 1944—Helminth parasites of the gray fox. Jour. Mammalogy 25:185-188.
5. CHADDOCK, T. T. 1939—Report on gray and red fox stomach examinations. Wisconsin Cons. Bull. 4(9):53-54.
- 5a. CHANDLER, ASA C. 1944—A new species of *Mesocoeloides*, *M. kirbyi*, from *Canis latrans*. Jour. Parasitol. 30:273.
6. CHITWOOD, B. G. 1931—*Physaloptera praeputialis* from *Urocyon* sp., in Virginia and *Lynx rufus*, Nevada. Jour. Parasitol. 18:53.
7. ——— 1933—Does the guinea-worm occur in North America? Jour. Am. Med. Assoc. 100:802-804.
8. ——— 1938—The status of *Protospirurura* vs. *Mastophorus* with a consideration of the species of these genera. Livr. Jub. Prof. Travassos, Rio de Janeiro, Brazil; 115-118.
9. FAUST, ERNEST CARROL. 1937—Mammalian heart worms of the genus *Dirofilaria*. Festschrift Nacht, Hamburg; 131-139.
10. GOBLE, FRANS C.—Correspondence to the Author, November, 1942.
11. GOBLE, FRANS C. AND ARTHUR H. COOK. 1941—Some lungworm records from foxes in New York. Jour. Mammalogy 22:456.
12. ——— 1943—Notes on nematodes from the lungs and frontal sinuses of New York fur-bearers. Jour. Parasitol. 28:451-455.
13. HAMILTON, PAUL CLARY. 1940—A new species of *Taenia* from a coyote. Tr. Am. Micr. Soc. 59:64-69.
14. HANSON, K. B. 1932—Parasites of ranch foxes and their treatment. Jour. Am. Vet. Med. Assoc. 80:202-212.
15. HARTLEY, J. 1938—Pathology of *Dirofilaria* infestation. Zoologica 23:235-245.

16. HATFIELD, DONALD M. 1939—Winter food habits of foxes in Minnesota. Jour. Mammalogy 20:202-206.
17. HOBMAIER, M. 1942—Newer aspects of the lungworm (*Crenosoma*) in foxes. Am. Jour. Vet. Res. 2:352-354.
18. KINGSCOTE, A. A. 1930—A case of paragonimiasis in the Ontario domestic fox. Rept. Ontario Vet. College 1930:40.
19. LARUE, G. R. AND G. H. BARONE. 1932—*Alaria oregonensis* from the coyote (Trematode: Alariidae). Tr. Am. Micr. Soc. 51:199-208.
20. LARUE, G. R. AND A. M. FALLIS. 1936—Morphological study of *Alaria canis* N. Sp. (Trematoda: Alariidae), a trematode parasite of the dog. Tr. Am. Micr. Soc. 55:340-351.
21. LAW, R. G. AND ALLEN C. SECORD. 1933—Control of lungworm in silver foxes. No. Am. Vet. 12(6):42-44.
22. LAW, R. G. AND A. H. KENNEDY. 1932—Parasites of fur-bearing animals. Bull. 4. Dept. of Game and Fisheries, Ontario.
23. LEIGH, W. HENRY. 1940—Preliminary studies on parasites of upland game birds and fur-bearing mammals in Illinois. Ill. Nat. Hist. Surv. 21:185-194.
- 23a. LOEWEN, SOLOMON L. 1929—A new cestode, *Taenia rileyi* N. sp., from a Lynx. Parasitology 21:469-471.
24. MACGREGOR, ARTHUR E. 1942—Late fall and winter food of foxes in central Massachusetts. Jour. Wildlife Manag. 6:221-224.
25. MORGAN, BANNER BILL. 1940—The Physalopterinae (Nematoda) of North America. Jour. Parasitol. 26 Supp. Absts. 40.
26. ——— 1941—A summary of the Physalopterinae (Nematoda) of North America. Proc. Helminth. Soc. Wash. 8:28-30.
27. OLSEN, O. WILFORD, FENSTERMACHER, R. AND B. S. POMEROY. 1937—The coyote as a host to *Physaloptera felidis* Ackert. Cornell Vet. 27:327.
28. PARNELL, I. W. 1934—Animal parasites of northeast Canada. Can. Field-Nat. 48: 111-115.
29. RILEY, WILLIAM A. 1916—The occurrence of the giant nematode *Diectophyme renale* (Eustrongylus) in the United States and Canada. Jour. Am. Vet. Med. Assoc. 49:801-809.
30. ——— 1933—Reservoirs of *Echinococcus* in Minnesota. Minnesota Medicine 16: 744-745.
31. ——— 1939a—Maintenance of *Echinococcus* in the United States. Jour. Am. Vet. Med. Assoc. 95:170-172.
32. RILEY, WILLIAM A. 1939b—The need for data relative to the occurrence of hydatids and of *Echinococcus granulosus* in wildlife. Jour. Wildlife Manag. 3:255-257.
33. SKINKER, MARY SCOTT. 1931—Three new parasitic nematode worms. Proc. U. S. Nat. Mus. 79:1-9.
34. ——— 1932—*Molineus patens* (Dujardin, 1845) Skrjabin and Schulz, 1926, collected in the United States. Jour. Parasitol. 19:91.
35. ——— 1935—Two new species of tapeworms from carnivores and a redescription of *Taenia laticollis* Rudolphi, 1819. Proc. U. S. Nat. Mus. 83:211-220.
36. SMITH, LAWRENCE F. 1943—Internal parasites of the red fox in Iowa. Jour. Wildlife Manag. 7:174-178.
37. SPERRY, CHARLES C. 1941—Food habits of the coyote. Wildlife Res. Bull. 4. U. S. Fish and Wildlife Service; 64-65.
38. SWALES, W. E. 1933—A review of Canadian helminthology I-II. Canad. Jour. Res. 8:468-482.
39. VOLKMAR, FRITZ. 1929—*Diectophyme renalis*, a little-known parasite of silver foxes. Vet. Med. 24:499-500.

The Harbor Seal in Washington State

Victor B. Scheffer and John W. Slipp

CONTENTS

Introduction	373	Parasites	400
The Type Specimen		Length of Life	401
of <i>Phoca vitulina richardii</i>	374	Breeding Habits	401
Size	375	Season of Birth	401
Adult Pelage	378	Place of Birth	403
Fetal and Juvenal Pelage	382	Number of Young	405
Skull	385	Care of Young	405
Distribution	385	Development of Young	406
Habitat	387	Mating	408
Seasonal and Daily Movements	388	Food Habits	410
Behavior on Land	389	Species Eaten	410
Behavior in Water	390	Amounts Eaten	410
Voice	395	Method of Eating	412
Fighting and Play	395	Economic Status	413
Scats	396	References	415
Enemies	397		

Introduction

Harbor seals are widely distributed in the temperate and arctic waters of the Northern Hemisphere. They are tolerant of the advance of civilization and are often seen by the hundreds in the vicinity of busy seaports and fishing communities. On the coasts of the State of Washington alone there are at least 5000 seals throughout the year. In spite of the many opportunities to observe harbor seals, however, certain aspects of their natural history are as yet imperfectly known.

We have attempted to gather in person and by conversation with professional seal hunters data on the behavior of harbor seals in the waters of Puget Sound, the Strait of Juan de Fuca, the Washington seacoast, and the lower Columbia River. For purposes of comparison, references are occasionally made to published information on the habits of seals in other parts of the world.

We gratefully acknowledge the help of friends in the Fish and Wildlife Service, U. S. National Museum, American Museum of Natural History, State of Washington Department of Fisheries, Washington State Museum, College of Puget Sound, Grays Harbor Junior College, Carnegie Museum, California Museum of Vertebrate Zoology, United States Coast Guard, and British Columbia Provincial Library and Museum. Dr. Kelshaw Bonham and David C. Titus assisted with the photographic work and the preparing of specimens. Dean Hugo Winkenwerder kindly provided laboratory space for our studies at the University of Washington. In the following pages we have

acknowledged the individual help of persons whose experiences with harbor seals over many years have been valuable sources of information.

The Type Specimen of *Phoca vitulina richardii*

In 1861 and 1862, the British ship "Hecate," under command of Captain George Henry Richards, Hydrographer to the Admiralty, was surveying the coastline in the neighborhood of Vancouver Island, British Columbia. Aboard the ship was a surgeon, Charles B. Wood, who was interested in obtaining natural history specimens for the British Museum. Somewhere in the Fraser River he obtained the skeleton of an adult harbor seal and among the islands of Queen Charlotte Sound at the north end of Vancouver Island he purchased the head of a subadult seal from natives who were towing the animal alongside their canoe.

In 1864, John Edward Gray described a new genus and species, *Halicyon richardii*, on the basis of this material. (Proc. Zool. Soc. London, pt. I, 28. July, 1864.)¹ He did not designate a holotype, did not state the sex, date of collection, or catalog number of either specimen, and did not state to which of the two skulls his illustrations, figs. 1 and 4, pertained. Ten years later, however, he stated that the illustrations pertained to the Vancouver Island skull (1874, p. 4).

It is obvious from Gray's treatment of the matter that he considered the two specimens as syntypes. Little is now to be gained by designating either as lectotype, although Oldfield Thomas seems to have made an attempt in this direction. A letter from R. W. Hayman of the British Museum (Natural History) reads as follows: "We have both the specimens here, and I find that the late Oldfield Thomas has labelled the adult specimen as type of *richardii*. In the absence of any indication to the contrary it seems right to recognize Thomas' decision to treat the adult specimen as holotype. Its B. M. catalogue number is 1431 a. We have no indication of the date of collection" (September 3, 1942).

Further information has recently been furnished in letter of March 11, 1943, from Martin A. C. Hinton, Keeper of the Zoological Department, British Museum. "To advance our long drawn-out correspondence about the type material of Gray's *Halicyon richardii* I am writing to say that (1) Gray accidentally transposed the Register numbers of the two specimens in his Handlist of 1874. The skull and skeleton from British Columbia, Fraser River, chosen by Oldfield Thomas as 'lectotype,' is really 1431.a (B. M. no. 61.10.9.8); the skull from Vancouver's Island, figured by Gray . . . is really 1431.b. (B. M. no. 64.2.19.1). In selecting the skull and skeleton rather than the figured skull as lectotype Thomas may have been misled by Gray's mistake in the numbers; for an old label in Thomas' handwriting, which accompanies the skull and skeleton, gives the locality as Vancouver's Island whereas it

¹ Gray's article, printed from the same galley but with change in paging, appeared again in 1864 in the *Annals and Magazine of Natural History*, ser. 3, 14:304-311. The exact date of publication of these journals is unknown.

should be Fraser River. (2) I think the true view of the matter is that the two specimens should be regarded as co-types. If a lectotype must be chosen then, in my opinion, it should be the figured skull. So far as I remember Thomas' selection of the other specimen has not been published; it is only a M. S. selection and as the selected specimen has a less definite locality it should be disregarded. (3) No penis bone is preserved with the specimen [skeleton]. Thomas seems to have inferred the sex from the general character of the skull. I suspect he was right, — he was a very good judge of such things."

For the probable date when the specimens of Gray were collected we are indebted to M. C. Holmes of the British Columbia Provincial Library, who writes that the "Hecate" arrived in New Westminster (mouth of the Fraser River) on March 23, 1861, and lay in Queen Charlotte Sound on two occasions, April and September, 1862.

IN SUMMARY, the syntypes of Gray now stand:

British Museum no. 61.10.9.8, original no.1431.a. Broken skull and skeleton of adult collected on Fraser River, British Columbia, in 1861, by Charles B. Wood. [Judged to be a male and designated as lectotype by Thomas, unpublished].

British Museum no. 64.2.19.1, original no.1431.b. Skull of subadult collected in Queen Charlotte Sound, British Columbia, in 1862, by Charles B. Wood. [Figured in Gray's original description, P. Z. S., 1864, p. 30, figs. 1 and 4, and therefore the principal basis of *Halicyon richardii*].

Gray's new genus was short lived. In 1872, Lord Walsingham sent another skeleton of a Pacific harbor seal (from San Francisco, California) to the British Museum and in 1873 John W. Clark examined the three specimens then accumulated in the museum and concluded that *Halicyon richardii* was a synonym of *Phoca vitulina* L.

In 1902, J. A. Allen stated that "the name *richardii* is available for the Hair Seal of Vancouver Island and neighboring coasts, and is the first name unequivocally pertinent to any North Pacific seal of the *Phoca vitulina* group" (p. 467). Although recognizing its affinities with *Phoca vitulina*, Allen chose to maintain the full specific status of *richardii* (op. cit., p. 491).

J. Kenneth Doult seems to have been first to use the combination *Phoca vitulina richardii* (1942, p. 116).

Size

The measurements of 74 seals taken at a single locality in Washington by bounty hunters are given in Table 1. We have subsequently obtained larger specimens: a male weighing 256 pounds and measuring 1700 mm. (67 inches) in a straight line from nose to tip of tail; a pregnant female weighing 243 pounds and measuring 1285 mm. (50.5 inches). It should be cautioned that, while the arithmetic means of the 37 males and the 37 females arrayed in Table 1 may give the impression that the sexes are similar in size, such is not

the case. The statistics on which the table is based were not obtained by representative sampling. In an attempt to compare only animals of a similar age, or at least adults, we have made another array using the weights of the 20 largest males and the 20 largest females from Nisqually (data selected from Tables 1 and 2) and have used the geometric mean as an expression of the average size of each group. The mean weights of the two groups are, respec-

TABLE 1.—Length and weight of 74 harbor seals (*Phoca v. richardii*) from the mouth of the Nisqually River, Washington, 1925-1930.

(Data from unpublished notes of T. H. Scheffer and from Scheffer and Sperry, 1931, pp. 216-222.)

Date	Length, tip of nose to tip of tail, inches	Weight, pounds	Date	Length, tip of nose to tip of tail, inches	Weight, pounds
37 Males			37 Females		
March 1	.....	252	Jan. 12*	.....	217
Feb. 14	65	246	May 18*	63	173
March 29	64½	216	Aug.	62	155
Feb. 19	.....	195	July 8	61	207
Jan. 6	.....	195	June 19	61	197
Jan. 12	.....	194	July 20	59	178
Feb. 4	.....	191	July 3	58½	169
May 26	61	185	May 13	57	165
Feb. 3	61	173	April 20	56	157
Jan. 22	.....	147	May 4	54	151
Jan. 6	.....	142	March 15	.....	151
Jan. 22	.....	139	May 13	55½	149
Dec. 31	52½	109	Sept. 10	54	120
Feb. 12	.....	106	May 12	49½	123
March 4	.....	97	March 28	49	114
March 15	.....	95	Sept. 2	49	103
Jan. 6	.....	94	June 25	49	97
Feb. 15	.....	84	Feb. 26	.....	86
March 1	.....	80	Jan. 7	.....	85
May 13	46	67	Feb. 3	46	85
May 15	45	49	Oct. 20	46	65
Nov. 30	44	45	March 28	45½	72
Dec. 4	43	53	Jan. 6	.....	72
Nov. 3	43	45	May 15	43½	47
Aug. 22	42¼	66	July 9	42	60
Aug. 21	42	78	Aug. 22	40	56
May 15	42	41	Jan. 12	.....	53
Jan. 11	.....	70	Aug.	40	51
Aug. 27	41	63	March 20	.....	50
Aug. 22	39	59	Dec. 20	.....	50
Aug. 22	39	51	Dec. 11	.....	49
Aug. 15	39	45	Dec. 20	.....	41
Oct. 20	38½	40	Oct. 21	39½	39
Aug. 22	38	48	Aug. 21	39	54
Jan. 20	.....	48	March 20	39	50
Aug. 8	36½	39	Aug. 15	35	34
Aug.	36	26	Aug. 22	33½	23
Mean	45.6	105	Mean	49.1	101

* Pregnant

by repre-
silar age,
f the 20
ed from
n of the
e, respec-
from the
d Sperry,

Weight,
pounds

217
173
155
207
197
178
169
165
157
151
151
149
120
123
114
103
97
86
85
85
65
72
72
47
60
56
53
51
50
50
49
41
39
54
50
34
23

TABLE 2.—Measurements of 14 Harbor Seals from Washington State, 1942.

	Males										Females									
	First summer					Subadult and adult					First summer					Subadult and adult				
Catalog number	{1051 JWS 7/13					153 1289 1288 1280					154 1255 1284 1290 154 1050									
Date collected	5/31 5/30 5/31 7/14 7/29 7/1					VBS VBS VBS VBS					VBS VBS VBS VBS									
Weight, in pounds	24 19 22 1/4 79 1/2 138					139 190 256 27 1/2					51 94 243† 168†									
Standard length	875 890 890 1060 1395 1440					1540 1700 910 963					1115 1240 1285 1443									
Length of tail from base, not standard	57 70 75 68 96					107 115 60 72					68 77 67									
Length of hindflipper, forward margin	188 204 197 235 270 290 323 338					193 199 213 216 245 290					230 343 343									
Expanded width of hindflipper	255 249 240 290 350 365 403 371					240 255 272 310 330 343					290									
Length of foreflipper, forward margin	172 180 196 190 255 245 236 270					175 188 210 230 200 242					242									
Expanded width of foreflipper	120 125 121 132 170 167 188 172					120 120 113 133 155 152					152									
Circumference behind foreflippers	510 400 475 790 910 900 1040 1190					490 660 670 810 1235 1025					1025									
Tip of nose to insertion of foreflipper	311 295 317 360 428 466 519 570 304					385 395 395 444					444									
Center of navel to tip of tail	292 300 318 403 483 497 524 588 305					318 343 408 378 495					495									
Center of anus to tip of tail	62 100 93 100 130 110 132 147 95					97 80 113 95 111					111									
Center of navel to center of anus	211 205 225 295 370 387 396 466 215					234 264 308 477 404					404									
Center of navel to tip of lower jaw	591 602 583 775 940 958 1053 1183 615					631 770 854 975 984					984									
Penis opening to center of anus	115 110 120 141 193 179 199 226					.....					.....			
Penis opening to center of navel	107 105 118 160 197 219 209 245					.....					.....			
Distance between mammae	.....					42					55 73 107 94								
From line between mammae to center navel	.....					41					48 60 121 77								
Center of eye to center of ear †	36 36 40 41 51 55 60 59 42 44					49 48 44 44 61					61									
Thickness of blubber on belly	17 75 97 84 106 115 103 77 122 78					103 81 90 125 118					118									
Longest nasal vibrissa	23 24 51 44 17 13 18					22 41					16									
Longest supranasal vibrissa	.....					.....					.....
Longest brow vibrissa	44 54 46 48 68					18 22					54									
Dimensions of testes or ovaries	13×25 12×24 10×25 31×65 23×47 30×70 31×70					12×21 11×18 4×11 8×17 12×26					12×26									
	.....					×33 ×26 ×19 ×27 ×41					.....								

* 1941. † In advanced pregnancy. ‡ Opened eye circular; diameter of eye (distance between lids) of largest male, 25 mm.

tively, 160 pounds and 129 pounds; in other words the adult males appear to be about 24 per cent heavier than the adult females. There is some evidence that seals weigh less in the winter than in the summer.

Table 2 gives more detailed measurements of 14 Washington seals examined by us. There are relatively few reference points on the body of a seal between which exact measurements may be taken and, for this reason, certain of our measurements exhibit a wide range of variation depending upon the judgment of the individual who made the measurements and upon the condition of the specimen, i.e., whether it was fresh, in *rigor mortis*, or relaxed. The standard length of the tail is, for example, a measurement utterly impossible to obtain with any degree of consistency. All measurements are straight-line caliper distances unless otherwise noted, and were made on the unskinned animal. Certain of the measurements should be explained, as follows:

Weight—entire animal, not bled.

Standard length—from tip of nose to tip of tail flesh, seal stretched on its back. (The curvilinear length, occasionally used by sportsmen, is a poor measurement in the case of the seal. Of 11 specimens measured by us the curvilinear length varied between 1.4 and 5.3 per cent greater than the standard length).

Length of tail—the altitude of the triangle that best approximates the shape and size of the tail, excluding hairs. (On a specimen with length of tail 72 mm. the hairs extended 7 mm. beyond the tip of the flesh).

Length of flipper—along forward margin, flipper held at right angles to long axis of body; from body to end of claw or flesh of first digit (claw extends beyond flesh of foreflipper, while flesh extends beyond claw of hind-flipper).

Expanded width of flipper—greatest width obtained by stretching flipper with moderate force.

Circumference behind foreflippers—seal lying on its belly. A slightly greater circumference can generally be obtained posterior to this plane, but bloating and shifting of the viscera make the latter measurement unsatisfactory.

Tip of nose to insertion of foreflipper—flipper held at right angles to long axis of body.

Dimensions of testes and ovaries—width and length of the fresh testis without epididymis; width, thickness, and length of fresh ovary.

Other reference points on the body require no special description.

Adult Pelage

Seen from a distance the dry pelage of the harbor seal appears light gray or tan. The body spots are visible, though not pronounced, almost as far distant as the seal can be identified. When the pelage is wet it appears dark, muddy gray, or even black, except where the sun may cause bright reflections.



Fig. 1. A 4-year-old male harbor seal in Point Defiance Aquarium, Tacoma, Washington, May 7, 1942. (Photo 1335 VBS).

Close at hand, the pelage exhibits a wide range of variation in color and pattern, depending upon the abundance or scarcity of dark spots and the whiteness or yellowness of the ground color. (A common pattern is illustrated in Fig. 2).

Allen states that "specimens from the Pacific coast present the same wide range of color-variations, and precisely the same phases as those from the shores of the Atlantic" (1880, p. 564). We have one specimen (1284 VBS), a 51-pound female, that has gray underparts almost without spotting (Fig. 16). Two fishermen told us that a pure white seal was seen on the Point Roberts Reef, Whatcom County, for three or four years previous to 1942. The drawbridge tender at Swinomish Slough, Camano Island, said that an almost white or "white dapple" seal was seen in the slough for two years. He saw it close at hand when it was shot in the spring of 1942. At the other extreme is a Fraser River female in the aquarium at Vancouver, B. C., whose body is almost entirely black.

Fred Irving told us that in his experience with hunting seals at Neah Bay he had found the males averaging darker than the females. Two of the darkest skins that we obtained at Nisqually are from males, but on the other hand,

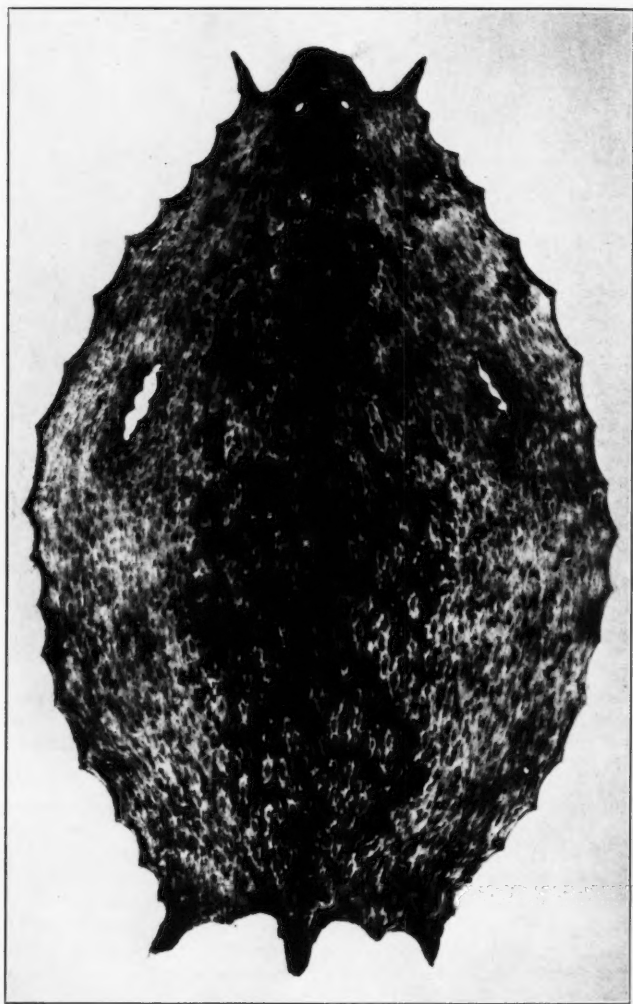


Fig. 2. Pelt of adult female harbor seal showing characteristic spotting. Neah Bay, Washington, May 19, 1942. The fleshed, dried pelt without flippers weighs 4 pounds 10 ounces and measures 1823 millimeters ($71\frac{3}{4}$ inches) from nose to tip of tail. Specimen no. 1272 VBS. (Photo 1379 VBS).

one male from here (1288 VBS) has a light grayish-tan ground color and grayish-chocolate spots. Of the European *Phoca vitulina* Hentschel states that the males are darker and the females more "kleinfleckig" (1937, p. 42).

There are scattered instances of marine organisms attaching to the pelage of seals. Barnacles (probably *Balanus*) and several species of marine algae (*Enteromorpha*, *Xenococcus*?, *Dermocarpa*) have been collected from seals that were crippled or pregnant, i.e., were hindered in their movements.

Molting of the pelage was observed on a four-year-old male kept through-out life in an open air, saltwater aquarium. Toward the last of August, 1942, the molt started to show on his hind parts. The old hair was characterized by a brownish cast over both the ground color and the spots, while the new hair was sleek and silvery gray. On September 14 the new hair covered the midline of the belly, periphery of the tail, rump, flanks, top of head and part of muzzle. Patches of the old hair could easily be brushed out by hand. On September 25 the molt was nearly complete. The old brown hair remained only in a strip down either side of the neck from the angle of the jaw to the shoulder; the right strip nearly meeting the left strip in the throat region. On November 25 the seal was a beautiful, sleek, silvery gray with shorply contrasting solid black spots and ring-shaped spots.

In a herd of 60 seals on Nisqually Flats, October 7, 1942, various stages of molting were apparent. Two seals, at least, were a uniform leaf brown only slightly darker than the sere brown of the salt marshes at this season. Some seals were brownish gray, others were approaching the silvery gray of weathered wood. The brown ones were nearly unspotted while the gray ones were sharply spotted with black, often with conspicuously light faces. In the *Phoca vitulina* of Holland the "Haarausfall" occurs in July in yearlings, and in August or early September in adults (Havinga, 1933, p. 83).

Brief study has been made, by means of a hand-lens, of the color and arrangement of the hairs on the back of a 45-pound male seal, probably 3-4 months old, taken on September 10 (Fig. 3). The *overhairs* are about 11 mm. long and are either uniformly white or are dark brown almost to their tips. The tips of all hairs, including those of the underfur, are white. The *underhairs* are easily distinguished from the overhairs by their smaller diameter and curly texture. They are not abundant enough to form a true "fur" layer (in the commercial sense) but they do compose a definite stratum whose outer surface is about 5 mm. distant from the skin.

Above each eye on adult seals there are 4 or 5, usually 5, brow vibrissae up to 68 mm. in length; above each nostril is a single supranasal vibrissa up to 24 mm. in length; and beside each nostril are 7 rows with a total of 42 vibrissae up to 125 mm. in length.

There are five claws on each flipper. The claws on 3 large adults (2 males and 1 female) in our collection are similar and have an average length as follows, starting with the first digit:

Foreflipper	42.	39.	36.	33.	30
Hindflipper	34.	24.	27.	25.	25

The claws of the foreflippers are used by the seal in travelling on land under certain conditions (Fig. 7). On a freshly-killed, 139-pound male (1288 VBS) the claws were colored as follows: hind claws horn, slightly darker at base; fore claws dark pearly gray dorsally, light horn colored ventrally.

Fetal and Juvenal Pelage

We have examined the pelage of six unborn seals taken in Washington (in order of increasing size):

1. Nisqually, February 18, 1933, alcoholic, male
2. Nisqually, January 12, 1928, alcoholic, male
3. Neah Bay, March (?), 1942, flat skin, sex ?
4. Neah Bay, May 19, 1942, flat skin, sex ?
5. Nisqually, July 13, 1942, study mount, male
6. Willapa Bay, May 31, 1942, study mount, female



Fig. 3. Pelage of harbor seals: (left) fetal and (right) subadult. Both samples were taken from the dorsal region between the shoulders; the view is of the under side (blubber side) of the leather with hairs extending posteriorly beyond the cut edge; magnified 4 diameters. Fetal skin, air-dried specimen no. 1272 VBS. (Photo 1441 VBS). Adult skin, chemically-tanned specimen no. 1255 VBS. (Photo 1290 VBS).

In this series three progressive changes in type of pelage can be traced: 1) an early, sparse fetal coat, perhaps the forerunner of the third coat, 2) a long, silky lanugo, and 3) a short variegated coat.

The February fetus (wt. 4.47 oz.) is cream-colored and virtually hairless, although close examination reveals a pattern of minute pits giving a satiny texture to the skin, and vibrissae are present on the head.

The January fetus (wt. 2 pounds, 7 ounces) is pale tan, with faint gray spots on both upper and under surfaces that foreshadow the pattern of the adult (Fig. 14). The upper surfaces of the flippers and tail are washed with light gray. With minor exceptions, the body is covered by hair over all areas that are hair-covered in the adult. The hair on the face is longest, up to 3.6 mm., fine and silvery. Behind the head the hair becomes progressively shorter and finer until, over the rump region, it is almost invisible. Evidently the long, silvery-white lanugo which is found lying unattached around the body of the full-term fetus is, in the present specimen, just appearing on the head region and would have progressed backward to cover the entire body.

The next specimen in the series is a dried skin taken "sometime in March" 1941, by a native of Neah Bay (Fig. 4). A section of the pelt from the middle of the back appears to be ashy gray, but under a hand lens the individual hairs are transparent or silvery. Spotting is visible but faint, and is restricted to the mid-dorsal region. The spotting is caused by the presence of light brown hairs, uniformly colored to their bases, among the more numerous silvery gray hairs. The hairs on the back are about 12 mm. long.

The May 19 specimen is also a dried skin (Fig. 3). The pelage is darker, i.e., with more brown and less silvery than the March fetus and the spotting on the back is more extensive. The hairs on the middle of the back fall into two groups, a coarser series reaching a length of 23 mm., and a finer series attaining a length of 8 mm. The shorter hairs are found with difficulty among the more numerous long hairs. The longest hairs are thus about twice the length of those on the March fetus. We are uncertain what the short series of underhairs represents, but the hairs are probably destined to compose the short, spotted coat of the newborn pup. This fetus was probably a month from parturition.

On the July specimen (wt. 24 pounds) the silvery gray lanugo is still attached from the base of the neck to the base of the tail, but has been shed from the top of the tail, flippers, and head. The lanugo is about 20 mm. long and can easily be removed with the thumb and forefinger, exposing the spotted undercoat.

The specimen taken on May 31 (wt. 27½ pounds) was undoubtedly ready for parturition (Fig. 5). It has the pelage typical of an adult except that the ground color is whiter and there is a strip down the middle of the back where the tips of the hairs do not curl forward as in the adult. This strip is 10-15 cm. wide and extends from the base of the neck to the rump. The hair on the back is about 8 mm. long. No trace of lanugo persists on the body, although

wads of it were found in the rectum of the fetus and more than a liter of loose hair was scattered in the amniotic fluid. The loose lanugo was 15-20 mm. in length.

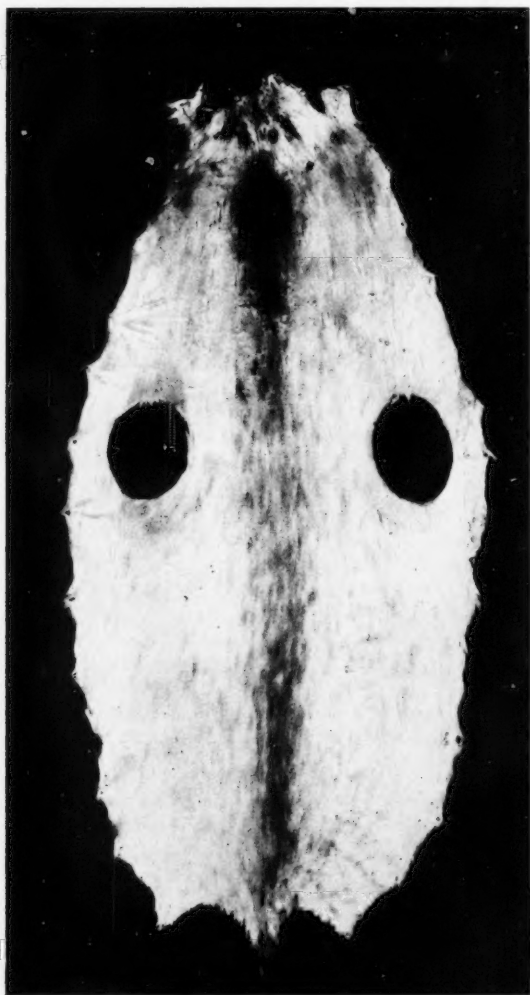


Fig. 4. Pelage of fetus at approximately half term showing abundance of long, silvery hairs, or lanugo. Length of dried pelt 641 mm.; Neah Bay, Washington, March 1942; specimen no. 1275 VBS. (Photo 1381 VBS).

Whether the harbor seal is born with the long, soft, white fetal pelage or whether this is shed before birth has long been the subject of conjecture. In some parts of North America, probably in the colder waters, the fetal coat may persist for a few days after birth. From our own studies and from information supplied by seal hunters we conclude that the harbor seal in Washington is normally born with the short, spotted coat.

Skull

A discussion of the skull of *Phoca vitulina richardii*, based in part on 13 specimens from Washington State, is presented by Doutt (1942, pp. 83, 112, 115). He points out that there is considerable individual variation in the skull of *Phoca vitulina* and that it is difficult, or in some cases impossible, to determine the race to which a specimen belongs by its skull alone. There are, however, certain average differences. In about 88 per cent of the skulls of the Pacific races *richardii* and *geronimensis* the premaxillae extend posteriorly along the nasals for 8-10 mm., while in only 14 per cent of the skulls of the Atlantic race *concolor* does this condition appear. Doutt is reluctant to present any skull characters by which specimens from the American and Asiatic sides of the Pacific may be separated.

"Sexual variation in the skull, at least in *P. hispida* and *P. vitulina*, is not pronounced, and without good series of properly sexed skulls it is difficult to demonstrate" (op. cit. p. 99). No characters are given by which sex can be determined. Allen (1902, p. 468) states that the teeth of the male in *P. v. concolor* are much stronger than those of the female. We have not found this character pronounced.

In *Phoca v. richardii* the permanent teeth have replaced the milk teeth by the time the pup is born. No teeth can be felt or seen in the mouth of a January 12 fetus (2 pounds 7 ounces) in our collection. The teeth of a young male harbor seal (1120 JWS) captured on May 30 at an age of about one week were examined. Protruding from the gums were the points of 30 teeth which we interpreted as being:

Upper: 3 incisors, 1 canine, 4 premolars, 1 molar = 9
Lower: 1 incisor, 1 canine, 3 premolars, 1 molar = 6

Another lower incisor and the fourth lower premolar were present in the jaw but had not yet appeared through the gum. On the lower molar the tips of 2 cusps were exposed; on all other teeth a single cusp was exposed. Subsequent discovery of an illustration by Weber (1927, 1:266, fig. 199) of the upper teeth of a newborn *Phoca vitulina* leads us to believe that certain of the small crowns in our specimen which we interpreted as permanent teeth might actually have been the tips of vestigial milk teeth which were later lost in the process of cleaning the skull.

Distribution

Six subspecies of *Phoca vitulina* are currently accepted as valid. The complete range of the subspecies *richardii* is given by Doutt as the "American side of the North Pacific Ocean" (1942, p. 117). On the south it appears to inter-

grade with the darker *geronimensis* of Lower California, and on the north with *largha* of the Asiatic shore and Bering Sea. The boundaries of its range are poorly understood because of the scarcity of study specimens.

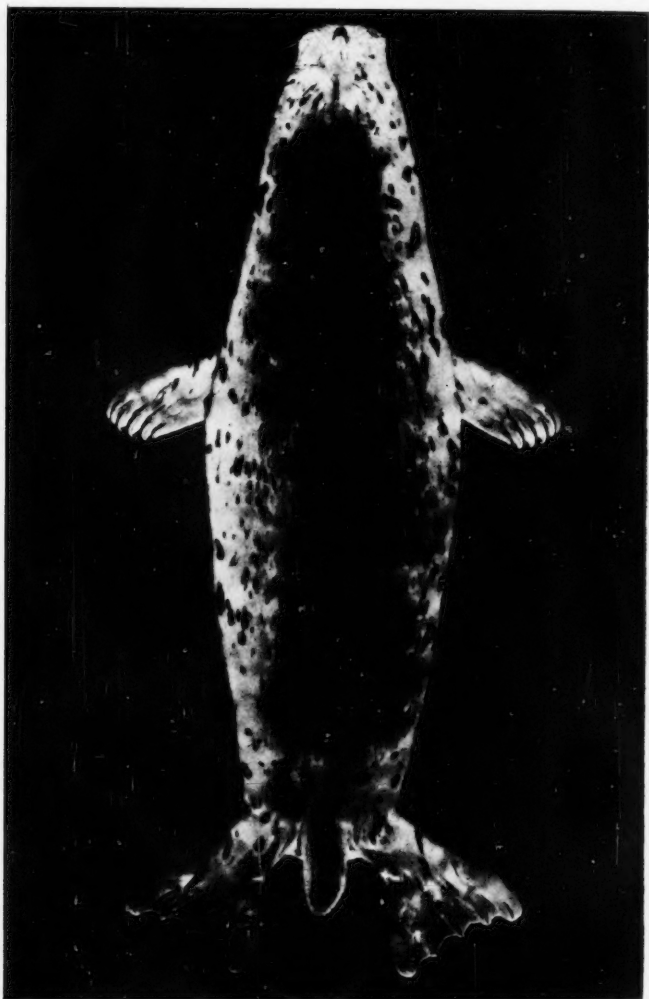


Fig. 5. Pelage of fetus within a few days of birth. Weight of fresh, entire carcass $27\frac{1}{2}$ pounds, length 910 mm.: Willapa, Washington, May 31, 1942; specimen no. 154 KB. (Photo 1383 VBS).

Harbor seals are widely distributed in the State of Washington. They occur along the coast in the shelter of bays or rocky points, seldom, according to fishermen, beyond 15 miles from shore. They also occur in the enclosed marine waters of the State and in the mouths of the larger rivers. For the sake of brevity we have omitted a full account of the specific localities in Washington where seals are known to occur. It is sufficient to state that important breeding grounds are found at Willapa Bay, Grays Harbor, Destruction Island, Neah Bay, Dungeness Spit, Minor Island, several of the smaller San Juan Islands, and the deltas of many rivers, including the Fraser, Samish, Skagit, Stillaguamish, Snohomish, Nisqually, and Columbia.

Harbor seals do not, to our knowledge, habitually enter any of the Washington lakes, although they are present in Harrison Lake, British Columbia, a few miles north of the International Boundary. In this locality, seals are found at least 5 miles up the stream that feeds the lake, and approximately 115 miles from salt water. According to the operator of the local mail boat, they are seen in the lake throughout the year.

Bonham (1942) reported the occurrence of two seals in Lake Union, Seattle, Washington. We examined his specimen taken on December 1 and found it to be a male approximately 6 months old, starved and without a trace of blubber.

We venture to state that there are 5000 harbor seals in the State of Washington. There may be twice this many but there are certainly no fewer. State records for the five-year period 1922-1926 show that 3200 seals were bountied. To this should be added about 40 per cent to account for seals killed but not recovered.

Habitat

Harbor seals are quite selective in choosing places to haul out on shore. Their resting places must satisfy two requirements: protection and ready access to food. Seals are invariably found where it is difficult or impossible for an enemy to approach unseen from the land side, that is, they crawl out on low sand bars, exposed rocks, or floating logs. They frequent shallow bays and tideflats where fish and shellfish are easily obtained. These tideflats are commonly the deltas of streams that carry important runs of salmon at certain seasons of the year, at which times the seals are in a position to catch the salmon as they start upstream. As mudflats are exposed by the falling tide, the seals crawl out of the water and lie side by side about 5-25 feet from the water's edge, often in groups of several hundred (Fig. 6). They are careful to remain within easy access of water of sufficient depth (1-2 feet) to enable them to make a speedy getaway in case of alarm. Frequent avenues of escape are the long sloughs that meander through the mudflats. On the other hand, seals will crawl out to rest at *high* tide in situations, such as on floating log rafts or grassy flats above the tidal zone, where there is no ready access to water at the period of low water slack.

Seasonal and Daily Movements

The harbor seal is not known to migrate. In this respect it differs from certain of the eared seals, for example, the Alaska fur seal which may travel 4000 miles in the course of a yearly cycle. The harbor seal sleeps on land and is distinctly a creature of inshore waters.

The lightkeeper on Smith Island told us that from 50-75 seals are constantly present on nearby Minor Island, with perhaps more in summer than winter. A long-time resident of Dungeness Spit stated that there are more seals on the spit in summer than in winter, partly, of course, because of the birth of the young in early summer. An Indian at Lapush told us that the seals frequent different rocks in the winter than in the summer, partly because of the winter storms on the open ocean.

Of the Atlantic race *concolor* Allen states "*Phoca vitulina* is so strictly nonmigratory that wherever it occurs at all it is reported to be found at all seasons" (1880, p. 488).

Two professional seal hunters on Willapa Bay told us emphatically that during the summer the animals tend to congregate in herds, whereas in mid-winter they are seen singly or in small groups. On May 10, 1942, we saw a herd estimated at 150-200 seals lying side by side on a sandbar in Willapa Bay (Fig. 6). When we revisited the bay on September 30, 1942, we did not have an opportunity to get out on the water but were told by Dewey Barichio, who was killing seals for the State Department of Fisheries, that no more than 40 seals could then be seen on Oysterville Sands where there were hundreds in June.

On the other hand, seals are grouped about the same at all seasons of the year on the Nisqually River flats. On December 28, 1941, we saw two herds here with about 25 and 50 seals, respectively. On October 7, 1942, we flushed



Fig. 6. Characteristic group of harbor seals on a sand bar at low tide, Willapa Bay, Washington, May 10, 1942. (Photo 1322 VBS).

a group into the water and counted 59 heads. Similar groups of seals have been noted a half-dozen times during the spring and summer. Members of the Luhr family, who have lived at the mouth of the river and hunted seals for 20 years, say that there is no appreciable change in the distribution of the seals with the seasons.

In Willapa Bay, only a few miles from the ocean and the mouth of the Columbia River, the seals move with the seasons, probably in response to changes in weather and the food supply. In the upper reaches of Puget Sound the seals exhibit a more or less fixed pattern of distribution regardless of the season.

We conclude 1) that harbor seals are loosely gregarious when resting on land but as a rule are solitary when foraging, and 2) that their movements are regulated largely by the conditions of the local environment rather than by any inherent urge to wander.

Little is known about the comparative activity of seals during night and day. The influence of the *tide* is certainly stronger than the influence of light on the behavior of the animals. Herds of seals are observed sleeping, or resting, on land both day and night. Fishermen report that seals rob their nets at all hours. The growls of seals (fighting?) are often heard on land at night, and seals are encountered by fishermen in the dark a long distance from land.

Behavior on Land

The harbor seal travels slowly on land by a hitching motion of the body. When frightened, however, it slaps the foreflippers vigorously on the ground and pulls the body forward by rapid, caterpillar-like jerks, the hindflippers pressed together and held up out of the way. The belly is never raised from the ground, as with the sea lion and fur seal. The foreflippers and claws are forcefully applied to sloping mud banks where seals haul out to rest. As a rule, the only marks left by the movements of the body on land are wide "skid roads" and lightly brushed flipper marks (Fig. 7).

Where seals rest on land they commonly make shallow depressions by the squirming of their bodies. These beds are roundish or oval, 1-2 feet in diameter and 1-3 inches deep.

Toward dusk on June 30, 1942, on Nisqually Flats, we watched seals moving slowly on a flooding tide toward the grassy banks of a slough. Arrived at the bank, each seal selected a low place and by means of 5 or 6 quick jerks, pulled its body up over the edge. It then jostled its neighbors briefly and settled down. In an hour's time, some 25-30 seals had hauled out. Hauling-out marks on the banks of sloughs are seen here throughout the year.

The harbor seal is more agile than one might infer by casual inspection of its compact, heavy-set body at rest. The entire supple length of the body is used to perform feats that in a terrestrial mammal are handled by the limbs. A seal at the Point Defiance Aquarium, Tacoma, easily leaped in a single motion from the water to a platform 8 inches above the surface. It also stood erect for brief moments on its hindparts (Fig. 8).

Behavior in Water

So far as we are aware, the principal nature of the swimming impulse delivered by *Phoca vitulina* has not been correctly described. Even studies as carefully detailed as those of Howell (1929 and 1930) do not, we believe, indicate a true interpretation of this important point. Our observations of swimming have been made at the Point Defiance Aquarium, Tacoma, where

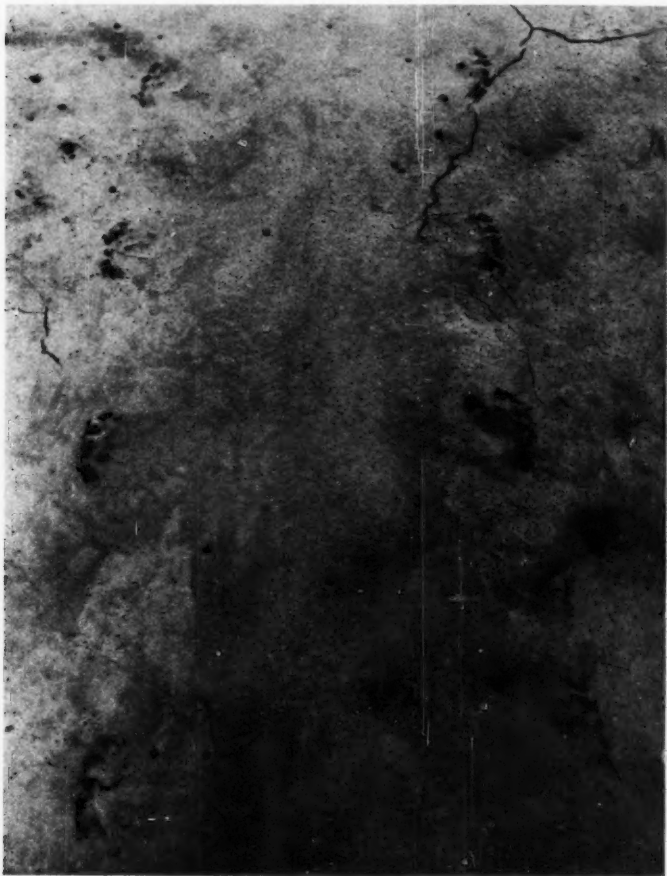


Fig. 7. Tracks of a harbor seal on damp, level silt at low tide, seal moving toward the foreground. Note claw marks of foreflippers and central path or skidroad where belly was dragged. Average distance between tracks (right to left) 50 cm.; average length of stride 40 cm.; average width of skidroad 29 cm. Nisqually Flats, Washington, July 29, 1942. (Photo 1454 VBS).

an adult male is kept in an outdoor concrete pool 14 feet long and 6 feet wide containing salt water 20 inches deep. As the seal is now well-grown, weighing close to 200 pounds, and the tank rather small for free maneuvering, it might be doubted that his swimming movements are normal. We have carefully and repeatedly checked, however, the movements of this animal under varying light conditions, and have also observed the movements of other captive seals of various sizes in aquariums in Seattle, Washington, and Vancouver, B. C. These observations are strengthened by the evidence of the anatomy of the flippers.

Descriptions of the swimming movements of *Phoca* invariably recognize the passive role of the foreflippers but state that the hindflippers are adpressed and utilized like the tail of a fish in vigorous lateral movements, or "sculled,"—implying a supplementary twisting motion to the main stroke. The fish analogy is a plausible and partly correct first concept inasmuch as propulsion is accomplished by means of side-to-side movements of these members. Actually, however, the feet act *alternately* and *separately* at a distance of several inches from each other, the swimming impulses generated by the twitching movements of the sacral region being strongly supplemented by coordinated *medial* strokes of the hind limbs and feet. The medial nature of the power strokes, a distinguishing feature of this mode of progression as contrasted to that of comparable types of fishes, is attested by the prompt expansion of the broadly webbed digital paddles at the beginning of each medial movement, followed by contraction during the lateral or recovering stroke. In this way the seal applies the combined power of his muscular torso and the highly specialized adductors of the hind limb against both undisturbed water (reached when the flipper expands at the beginning of the inward power stroke) and his own slip-stream. It seems likely that, owing to the proximity of the hindflippers to one another and the rapid succession of movements at even moderate speeds, the efficiency of the method is increased by the reciprocal counter-impulses of the alternate, medial impulses, tending to divert some of the lost lateral motion into thrust along the line of progression. Resistance to the lateral recovery movement of the flipper and shank is probably minimized by the sympathetic lateral displacement of the posterior portion of the streamlined torso. It is probable, moreover, that some degree of assistance is imparted to the forward progress of the seal by this lateral stroke of the hindflipper.

Infrequently both flippers deliver power strokes simultaneously, the expanded flippers sweeping together in a clapping motion. This maneuver was observed on one occasion as the seal launched itself backward from an erect sitting position on the bottom of the pool, and again at the end of a leisurely swimming tour of the pool.

The hindflippers can be turned palm upward (pronated) and in this position deliver upward strokes alternately or in unison, and singly or serially, thus acting as elevators for the moving seal, or at rest enabling it to elevate the anterior portions of the body higher than usual above water for brief periods. In the latter case the alternate, successive strokes of the submerged flippers make a continuous "boil" on the surface of the water directly above.

Supination of the hindflippers is apparently not possible, although the soles can be tilted at least a few degrees in that direction from the vertical. The seal is thus unable to send impulses to the surface when lying on its back with only the face above water, a position occasionally assumed. It can, however, by hand-like, clutching strokes send weak impulses forward toward the head.

A man who hunts seals from a power boat says that "when first pursued by a boat a seal can swim 12-15 miles an hour, more or less, depending upon the age and condition of the individual. After a half mile or so of pursuit, however, the seal slows down and can be overtaken and killed as it pokes its nose to the surface for air. . . . When shot and killed a seal usually remains on the surface for a brief time, but in about 40 per cent of the cases the seal sinks quickly and is lost" (T. H. Scheffer, MS).

At Nisqually on July 29, 1942, we watched a number of seals that were not over 2-3 weeks old with their mothers in the water. One pup that became separated from its mother swam ahead of our boat faster than we could row, surfacing repeatedly.

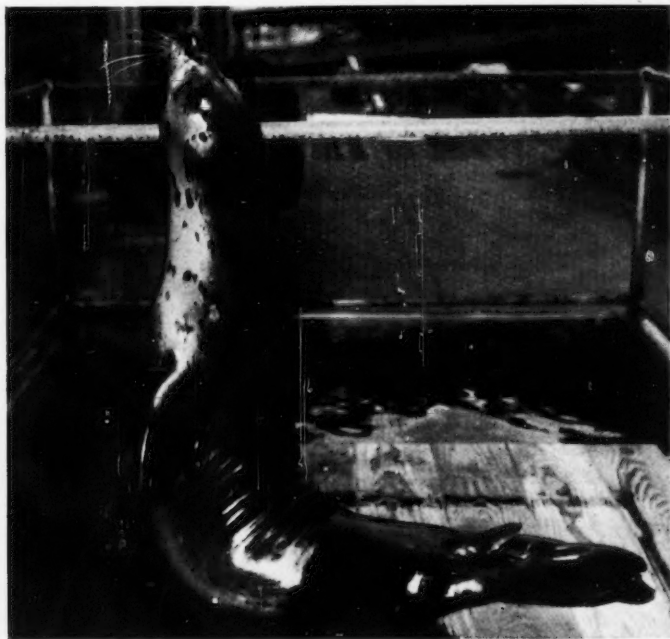


Fig. 8. A 4-year-old male harbor seal reaching for food in Point Defiance Aquarium, Tacoma, Washington, May 7, 1942. Note the flexibility of the trunk and the adpressed hindflippers. (Photo 1331 VBS).

William Luhr once drowned a seal by submerging a specially constructed floating seal trap in which the animal was imprisoned. As recalled several years later, the seal behaved normally for 29 minutes, then struggled frantically for 2 minutes, gave off bubbles of air, and expired.

About noon of a warm, midsummer day one of us watched an adult male *Phoca v. richardii* in the National Zoological Park. It rested on its side or back on the bottom of a concrete pool in 3 feet of water. At intervals of $3\frac{1}{2}$ - $4\frac{1}{2}$ minutes it rose to the surface, expelled air vigorously, and then breathed slowly and regularly for about 45 seconds. The nostrils opened and shut about 15 times at intervals of 3 seconds. No bubbles were expelled while the seal was under water.

The harbor seal has been unable to divorce itself as completely from the land as have the eared seals because it is apparently unable to sleep at sea. The northern fur seals (*Callophorus*) and the California sea lions (*Zalophus*) habitually float relaxed on their backs on the ocean swell for hours at a time. During the winter and spring the fur seals may not touch land for a period of 6 months. On the other hand, harbor seals seem habitually to sleep on land in the wild; an aquarium animal lying horizontally in the water asleep invariably assumes a prone position with the head submerged and is obliged to raise it every few minutes for periods of deep breathing.

An adult male seal at Haglund's Aquarium, Seattle, made a practice of slapping his foreflippers vigorously against his sides and chest, 4-5 times a second, with a loud smacking noise. He did this either while treading water, floating, or lying on a platform. If the act occurred while he was partly submerged the water flew in a sheet for 10-15 feet. It appeared as though the animal were deliberately drenching spectators.

An adult seal at Point Defiance Aquarium, Tacoma, observed several times in the spring and summer of 1942, had a similar habit of "applauding" with one foreflipper against his wet chest while floating at the surface, flank upward. A favorite trick of this seal was to make several submarine circuits of the tank, cruising slowly on his back, then suddenly splash water in the faces of the spectators who would retreat with loud shrieks.

This seal, and one in the aquarium in Seattle, habitually cruised around his tank under water, on his back or side, frequently rotating slowly on the long axis. Diving was accomplished head-first. Once, while lying still at the surface, he sank vertically a foot or more and then rose buoyantly to the surface without visible movement of his appendages. He often sat erect on the bottom of the pool with head and shoulders above water. This he accomplished by turning the posterior quarter of his trunk to one side, the hindflippers adpressed, forming a rather broad base at the back of one flipper and the lateral surface of the sacral portion of the trunk. We have never seen the harbor seal form a pedestal by extending the flippers laterad, the palms down.

On Nisqually Flats, June 30, 1942, at 1:00 p.m., we watched 30 seals lying on the outer fringe of the delta. They were lying with bellies awash where a small stream draining the mudflat emptied into the salt water. They

were splashing with hind and foreflippers and rubbing their hind flippers together. Their bodies were wet and glistening, probably cool in spite of the extreme midsummer heat.

While we were rowing a short time later a seal's head appeared at a distance from the boat. The animal watched us briefly, then dived forward into the water, exposing its entire back and flanks. Usually the harbor seal submerges quietly by a sinking motion rather than by diving (cf. Fig. 9).

In the evening of the same day we watched a seal demonstrate a peculiar pose that we had not seen previously. The animal was first noted with its head and hindparts protruding from the water, apparently with its back strongly arched in a U-shape, belly downward. The lower jaw was at or just above the surface, the crown uppermost, the hindflippers folded over the tail and held vertically. After remaining quietly for about 5 minutes in this pose, occasionally moving the head or mouth, the seal submerged. On reappearing, it swam slowly with its head above water in the normal posture, then, still coasting along, showed its back for 15-20 seconds, finally dropped its back and raised its head and hindparts out of the water as before.

On the Stillaguamish Flats on the morning of February 14, 1942, a herd of seals moved off the mud flats and out on the bay as the falling tide exposed



Fig. 9. Harbor seals alarmed and swimming rapidly past the observer. One is raising its head and body to a position for better observation; it subsequently went into a crash dive. Willapa Bay, Washington, May 10, 1942. (Photo 1330 VBS).

their resting grounds. We followed them cautiously in a rowboat to about one-half mile off shore, where we remained adrift. At one time, 65 heads were counted on the water around us, none closer to the boat than 200 yards. The seals moved back and forth slowly, often rising vertically out of the water to their armpits to see us more clearly. An occasional loud splash, audible for a mile, was heard. From observations of aquarium animals, we believe that this noise is caused by a forward crash dive.

We saw seals swimming submerged in brackish water known to be only 3 feet deep, where the wake was clearly visible on the surface. Here, and at other places, we have looked down through shallow water and seen disturbed paths on soft mud caused by seals swimming a few inches above the bottom. When seals leave a mud flat and swim through clear water they leave a cloudy trail behind them.

John Luhr, veteran seal hunter, says that he has seen seals lying quietly on the bottom in shallow water, waiting for a boat to pass by. He believes that this trait may enable seals to lie in wait for, and capture, active fish by rising to seize them from below.

Voice

Harbor seals utter a variety of sounds, among them the following:

1. A loud snort or *blouwf!* of about 1 second duration, audible for a mile or more.
2. A "squall, bawl, or throaty grunt" during the breeding season in the fall (not heard by us).
3. A series of dog-like notes heard by us from an adult male in an aquarium: *barf! warf! warf! . . . barf! barf!* often followed by, or interspersed with, protracted growls of several to many seconds duration, *rwoor. . . rarrwrr!*
4. A sheep-like *m-a-a-a* from the suckling pup.
5. A plaintive *kroo-roo-uh* or *kroo-roo*, each call lasting from $2/3$ to 1 second, heard from a suckling pup that had become separated from its mother in the water.

Fighting and Play

The skins of males are occasionally scarred as though from fighting. Several observers told us that the males charge head first in the water, seize each other by the neck, and grapple. Edward O. Pedersen said that on quiet fall evenings the seals are heard fighting on the sandbars, their bodies slapping loudly. William Luhr said that fighting is most severe at Nisqually during nights in October and November (the mating season is in the fall).

In general, the disposition of the harbor seal is remarkably mild. Seagulls walk unalarmed among the bodies of seals resting on sandbars. Young seals make gentle, intelligent pets; lively and with a decided "sense of humor." In an aquarium they often play with a bit of food as a cat plays with a mouse.

We observed 4 separate pairs of seals in the water off Nisqually Flats on the evening of June 30, 1942. They were engaged in behavior that might be interpreted either as ordinary play or the play of adults who would be mating later in the season. The tide was flooding on a warm, calm day, 5:00-7:00

p.m. Both single seals and pairs were moving toward land, riding the tide for the most part, one pair attaining less than one-quarter of a mile in 15 minutes. The two seals of a pair behaved like puppies, biting, ducking one another, surfacing briefly to splash and duel before again submerging.

A month later, we again saw here 2 pairs of seals engaged in play at the surface for nearly an hour. Their splashing could be heard for 300 yards. Brief glimpses of their heads, fore and hindflippers were obtained as they rolled and tumbled. The hindquarters often flapped on the surface with a loud splash. Two other pairs in the vicinity were behaving in a similar fashion.

Scats

Seals habitually defecate in the water. Although occasional scats are observed on land these are usually where a falling tide has exposed them and not in places where a seal would have crawled out on dry land to deposit them. A common type of scat is shaped like that of a medium-sized dog, in color brownish or dark gray, of a uniform, pasty texture. The scats are composed of fine particles, with the exception of fish otoliths and fragments of crab shells that resist the action of digestive juices.



Fig. 10. Scat of a harbor seal on a mud bar at low tide; color dark brown; dimensions of nearest piece 37 by 170 mm. Samish Flats, Washington, June 18, 1942. (Photo 1391 VBS).

After we frightened 200 seals from a sandbar at low tide in Willapa Bay a single seal scat was found, measuring 16 mm. in diameter and 47 mm. in length, of a dark brown color. On a sandy beach above tide level on Minor Island we noted several scats. One was dark reddish-chocolate in color, liquid, with a fishy odor, and was spread over a strip 2-3 inches by 4 feet. Two others nearby were tan; soft and sticky; the size of a man's hand and $\frac{1}{4}$ inch deep. From one a fish tapeworm was recovered.

On a mudflat at the mouth of the Samish River we saw a seal scat, brownish gray on the surface and muddy brown inside, 37 mm. in diameter and 170 mm. long; pasty (Fig. 10).

Two cylindrical, dark brown scats were noted on a sandbar at low tide in Padilla Bay, June 18, 1942, and another on Hat Slough the following day. We would have rowed past the latter location without realizing that it was a hauling ground for seals, had we not suddenly noticed the stale, fishy odor of the place. Fish scraps were never found on the hauling grounds, and the scarcity of scats was so pronounced as to leave in doubt the source of the strong fishy odor characterizing these place, unless urinary deposits were the principal factor. The bodies of seals are markedly odorless.

Enemies

The shyness of the harbor seal and its quick awareness of danger enable the species to persist in Washington under constant persecution by sport and commercial fishermen, trophy hunters, and target shooters. In general disfavor, it lives and reproduces within earshot of civilization and yet manages rather well to avoid its tormentors. It is a pity that the popularly supposed food habits of the animal have resulted in man becoming its greatest enemy. We do not intend to dwell upon the methods by which the harbor seal is killed or captured by man but will mention briefly the important ones:

1. Hunting with a .25/20 or high-powered .22 rifle from a fast power boat. As the stunned seal slowly sinks it is recovered with a gaff hook.
2. Hunting with a harpoon and a tin-can float from a sea-sled with outboard motor.
3. Capturing in a net of the purse-seine type placed at the mouth of a slough when seals are known to be resting farther upstream.
4. Trapping on rocks with a No. 4 steel trap and drowning weight. A floating wooden live trap has also been tried, but seals have a tendency to shy away from a strange object of this kind.
5. Tangling in gaff hooks set on partly-floating logs or "dead-heads"; an extremely cruel method.
6. Dynamiting. On sandbars at the mouth of the Fraser River the British Columbia Department of Fisheries laid charges of dynamite to destroy seals on April 19, 1918; May 16, 1918; and June 6, 1919. The results were rather uncertain, as the bodies of the seals sank and could not be recovered. In one case, the bodies of four were found, and from the evidence of blood in the water it was thought that about 50 seals had been killed (letter of July 4, 1942).

The principal *natural* enemies of the harbor seal are evidently sharks and the killer whale. Mr. A. Garcin, superintendent of the whaling station on Queen Charlotte Island, B. C., wrote us that "a few years ago we caught a

shark at the station measuring approximately 20 feet and it had a hair seal in the stomach which it had swallowed the day it was caught as it was in perfect condition" (letter of August 9, 1941).

About August 25, 1936, Elmer O. Pedersen caught a shark estimated by him to weigh 800 pounds, in Willapa Bay ship channel. Its stomach contained a "medium-sized (about 30 pound) seal that had apparently been swallowed whole." (A seal pup at birth weighs 25-30 pounds.) The shark was said to be an uncommon species in Willapa Bay and was the same kind as another caught in the same place three days later, with a sturgeon in its stomach. We

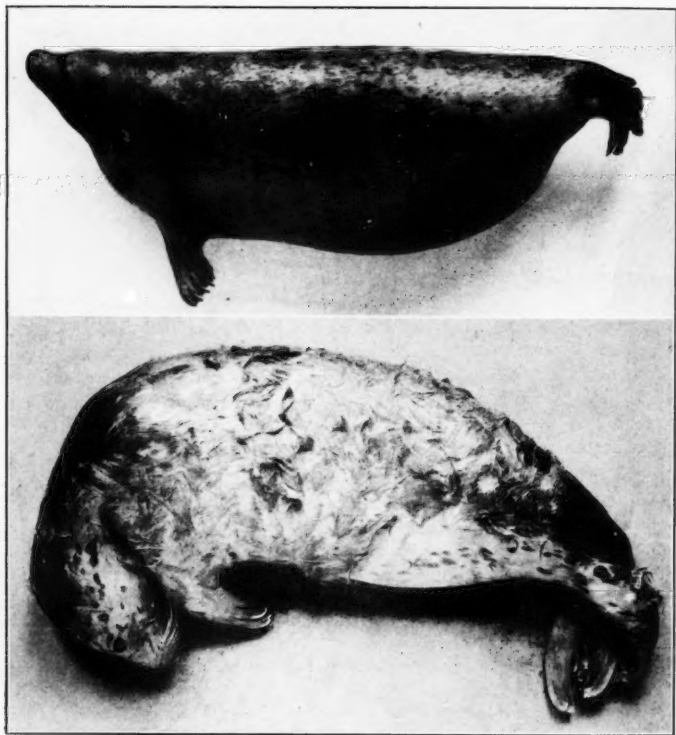


Fig. 11. (upper). Harbor seal near termination of pregnancy, a 243-pound female carrying a fully developed, $27\frac{1}{2}$ pound fetus. Willapa Bay, Washington, May 31, 1942, specimen no. 154 KB. (Photo 463 KB).

Fig. 12. (lower). Fully developed fetus, weight $27\frac{1}{2}$ pounds, removed from uterus. Willapa Bay, Washington, May 31, 1942, specimen no. 154 KB. Approximately 1 liter of lanugal hair was present in the amniotic fluid and matted on the surface of the fetus. Note protruding ear pinna and long, curved claws. (Photo 479 KB).

was loaned a photograph of the latter shark, labelled "342 pounds, 8 feet 2 inches long" together with 10 of its teeth. These materials were verified by Dr. Leonard P. Schultz as pertaining to the great white shark, *Carcharodon carcharias* (letter of June 9, 1942).

Dewey Barichio told us that 3 or 4 times he had taken large "mud sharks," 200 to 250 pounds in weight, in gill nets in Willapa Bay and found what he believed to be harbor seal remains in their stomachs. These objects were balls of flesh and hair the size of cantaloupes.

We have certain information on the taking of harbor seals by the killer whale, *Grampus rectipinna*. The killer whale, usually called in Washington State the "blackfish," is a regular visitor to Puget Sound, and schools of several dozen are not infrequently seen.

William Luhr told us of watching an encounter between seals and killer whales. He was hunting seals from a boat at the mouth of the Nisqually River and had succeeded in wounding two old males when he suddenly realized that a school of "thrasher whales" was close at hand. The whales were coming from the direction of open water (Anderson Island), probably in pursuit of harbor porpoises. The whales were from 30-40 feet long, some with a dorsal fin 2-3 feet long and others with a dorsal fin 6-7 feet long, with a shining, white, sickle-shaped mark 2-3 feet long on the side of the body behind the head. As the whales moved rapidly they pushed up a bulge of water 3 feet high in front of them. Several times a whale rose almost under the boat but did not strike it. The whales attacked at least three seals that were swimming in the mouth of the river, including the two that Luhr had wounded. Their method was to rise from below and strike the seal with the top of the head or snout, roll past and strike the seal a tremendous blow with the tail, knocking off chunks of fat and flesh as large as a man's two fists. The seals appeared to be helpless from fright or were stunned by blows and were easy victims. Luhr rowed toward each of the three victims but was too late to salvage the bodies. He saw them disappear but could not state positively that they were seized finally by the whales. After the whales left, he saw a school of small "harbor porpoises" leave the river mouth for the open water, and believes that these had been taking refuge while the whales were about. (We have often seen *Phocoena vomerina* in the neighborhood of Anderson Island.)

The lightkeeper at Port Simpson, British Columbia, writes of watching a group of six killer whales, often as close as 100 feet from the shore, in May 1919. They collided with each other and thrashed the water for a period of 20-30 minutes. "Then, right from under the noses of the big killers we saw a harbor seal spring over a small rock and with many flops make its way towards us, and eventually stop at our very feet. It looked up at us as though asking our protection, and seemed in no way afraid of us. It kept a watchful eye on its enemies, but seemed to feel itself safe from them. We could see its labored breathing, and noted how tightly its nostrils closed as it held its breath. We retreated as the tide rose, and the seal followed us, until the killers disappeared, when it made off to deeper water" (J. Moran, MS., May 15, 1924).

Parasites

The harbor seal is subject to a number of parasites, among them the stomach worm. Of seal specimens taken in enclosed waters of Washington from 1927 to 1930, Scheffer and Sperry state that "parasitic round worms (*Porrocaecum decipiens*), varying in numbers from a few to several hundred were present in all but 16 of the 100 seal stomachs. Eleven (approximately 70 per cent) of the worm-free stomachs were among the 47 collected during May, June, and July. It is of interest to note also that only 1 of the 21 seals examined in 1926 (suckling young not included) was free from stomach worms, and it was collected in May" (1931, p. 225).

The same ascarid was found by the senior author in a harbor seal from the Aleutian Islands and also encysted in the mesentery of the common cod, *Gadus macrocephalus*, from that locality.

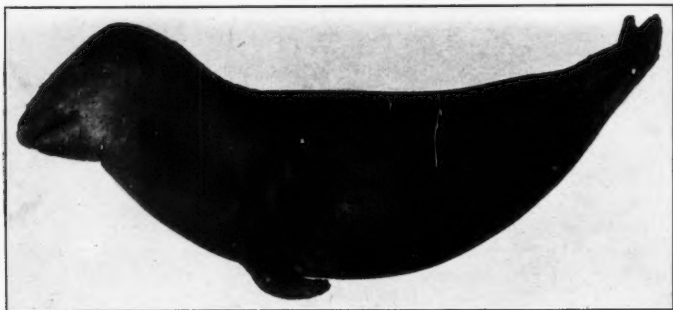


Fig. 13. Fetus of a harbor seal, male, weight 36.0 g (1.27 oz.), length along curves of back 103 mm. Willapa Bay, Washington, between September 12 and 15, 1941. Specimen no. 1264 VBS (in alcohol). (Photo 1310 VBS).

In connection with our studies of marine mammals, Dr. Benjamin Schwartz of the U. S. Bureau of Animal Industry kindly furnished us on March 18, 1942, with a list of the known parasites of certain hosts. In *Phoca vitulina* now fewer than 48 species of internal and external parasites have been recorded! We have personally observed only the ascarid *Porrocaecum*, the acanthocephalan *Corynosoma*, and the mite *Halarachne* in Washington seals, but undoubtedly many other parasites would be uncovered by special investigation.

An interesting arachnid parasite, *Halarachne halichoeri*² occurs in the nasal passages of certain prinnipeds. A first-stage nymph of this mite was collected from adult male seal No. 1280 VBS and about one dozen adult mites were collected from adult male seal No. 1288 VBS (see Table 2). The latter specimens were white, waxy, torpedo-shaped, and about 2 mm. long; attached to the mucosa of the pharynx.

² Identified by Dr. G. F. Ferris.

The entire 23-meter length of intestine of an adult male seal (No. 1288 VBS) was examined for parasites. There were no ascarids beyond the pyloric valve of the stomach. In the lower half of the small intestine individual specimens of an acanthocephalan, *Corynosoma strumosum*,³ were attached, often as abundant as one to the square inch. They were absent toward the lower end of the ileum. They were club-shaped, creamy white with yellow-brown on the tip of the small end, about 7 mm. long, and attached at the large end.

The occasional presence of barnacles and other marine organisms on the pelage of seals has been mentioned.

Length of Life

A male *Phoca v. richardii* in the National Zoological Park, Washington, D. C., is labelled as being a gift from the California Academy of Sciences, June 2, 1927. Ernest P. Walker says that when he first joined the staff of the Zoological Park in 1930 this individual was certainly here, and that the label is correct. The seal was active on August 22, 1942, at an age of over 15 years.

A female harbor seal lived over 12 years in the same institution (Hollister, 1925, p. 93).

A male *Phoca v. geronimensis* lived in the Balboa Park Zoo, San Diego, California, from May 30, 1924, to April 15, 1940. At the time he was captured he was thought to be "nearly grown" and at the time of his death he was therefore at least 17 years old (Benchley, 1937, p. 4, and letter of April 5, 1943).

Breeding Habits

SEASON OF BIRTH

For an animal as widely distributed on the Pacific coast as the harbor seal there is surprisingly little information on the breeding habits and development of the young. One reason may be laid to the extreme shyness of the animal and its habit of hauling out on exposed, low-lying terrain where an observer cannot approach without creating alarm. Another reason, which we discovered by following the behavior of seals for several years, is that the breeding season is not distinct but covers a period of 3-4 months, varying with the locality and the individual animal.

It is clear that the young are born earlier in Grays Harbor and Willapa Bay than on the inland waters of the State. A seal hunter and fisherman who is daily on the waters of Willapa Bay was asked in April 1942 to watch for the appearance of the first newborn seals of the season. He reported seeing the first pup on May 12. During May he captured six live pups and on May 31 we obtained from him a pup and a pregnant female with a late-term fetus.

At Westport, Grays Harbor, on May 23, 1942, Harold Barman found a live seal pup on a fisherman's float. The fisherman "saw it with its navel cord hanging a few days prior to this date." This pup was probably newborn, since

³ Identified by Dr. E. W. Price.



Fig. 14. Fetus of a harbor seal, female, weight 1,105 g. (2 pounds 7 ounces), length along curves of back 405 mm. Nisqually, Washington, January 12, 1928. Specimen no. 248,402 USNM (in alcohol). (Photo 36058-a USNM).

it was shorter (660 mm.) than either of the two late-term fetuses measured by us at 875 and 910 mm. respectively.

On May 26, 1941, Robert S. Bach and Stanley G. Jewett examined a small live seal on Long Beach Peninsula, Pacific County. The seal was very light in color and was dragging an umbilical cord about one foot in length. This pup may have been born in Willapa Bay or in the mouth of the Columbia River.

At Copalis, on May 29, 1942, John Stetson rescued a seal pup floundering in the ocean surf, possibly a pup that had been born in the shelter of Grays Harbor.

At Neah Bay on May 19, 1942, Fred Irving shot a pregnant female whose pup would not have been born for several weeks, as we judged from the condition of the fetal pelage.

It is thus definitely established that the pupping season begins in May in the coastal bays and perhaps along the ocean shore itself. Our evidence indicates that the season is from 1-2 months later in Puget Sound and adjacent waters, as will be presented in the following notes.

At Dungeness Spit on June 8, 1942, we were told by a long-time resort owner that no pups had yet been seen but that they were expected in late June. V. R. Carrie, who was light keeper here for six years, wrote us that "I have seen as many as 250 at a time. They have their young during the months of June and July."

The lightkeeper at Smith Island told us in April 1942 that the pups are born here in late June and early July. He reported later that on July 13, 1942, he saw two instances of a pup riding on its mother's back and on July 15 he found a fresh afterbirth on the beach. He also had a record of seeing a female and pup on July 10, 1939.

At Point Roberts, on the Canadian border, we were told by fishermen on June 16, 1942, that no seal pups had as yet been seen there.

Fred Kalso, renowned seal hunter of Bay View, Skagit County, told T. H. Scheffer that he saw the first pups of the season in Padilla Bay on July 4, 1928 (MS).

On Nisqually Flats, June 30, 1942, we positively ascertained that there were no young seals in the herd. William Luhr saw the first pups here on July 8. On this date he shot one with a dried 3-inch umbilicus attached, and captured another which he described as having "birth oil" on its hair. A female bearing a 24-pound fetus was taken here on July 13.

Luhr states that the pupping season at Nisqually is from very late June to very early August, and is at its height on the fourth of July.

PLACE OF BIRTH

Our information on this subject depends largely upon the accounts of persons who are believed to be reliable observers. It appears that the little seal may be born either in the water or on land, although a delivery in the water is uncommon.

According to the lightkeeper on Smith Island, afterbirths of seals are found on the sandspit awash at high tide, where the seal herd spends most of its time.

Edward P. Nelson of Willapa Bay said that on June 24, 1924, he and his partner cornered a herd of seals on Stackpole Slough and caught 116 of them in a net. The seals were clubbed and dragged upon the beach for scalping. As they worked, the tide rose and flooded them with water. Nelson ripped open one large female with a sweep of his knife and a pup rolled out and swam alongside in the shallow water. (Most of the Willapa Bay sandspits are flooded daily by tidewater so that the young seals are forced to swim nearly from the time of their birth.)

Dewey Barichio has seen newborn pups on many of the sandbars in Willapa Bay: 3 places in the channel, 3 or 4 near the ocean bar, and 5 or 6 near Long Island. On several occasions he has approached, by motorboat, a female with pup and seen evidence that the pup was born in the water, i.e., blood and

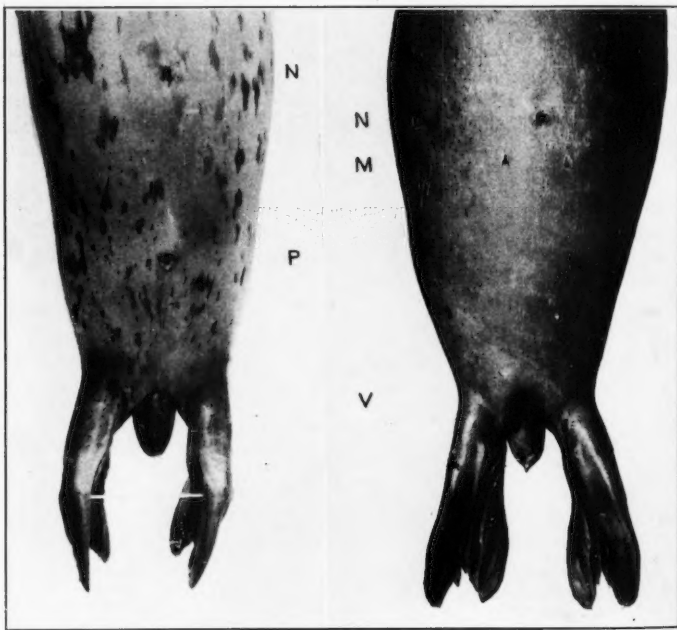


Fig. 15 (left). Genital region of male harbor seal showing navel and preputial opening, Willapa, Washington, July 30, 1942. Specimen no. 1288 VBS. (Photo 1452 VBS).

Fig. 16 (right). Genital region of female harbor seal showing navel, the two mammary, and vaginal opening. Nisqually, Washington, July 8, 1942. Specimen no. 1284 VBS. (Photo 1436 VBS).

afterbirth floating in the vicinity. (Might not the female have left a nearby sandbar in alarm while she was in the act of delivering her pup on land?)

NUMBER OF YOUNG

The female bears a single pup, rarely two. A hunter on Willapa Bay opened a pregnant female some years ago to obtain the scalp of the unborn pup and was greatly surprised to find two, rather than one, fetus. Another hunter remarked that he had found "perhaps a half-dozen" twins among the many summer fetuses that he had scalped for bounty. Three other veteran hunters stated that they had never found twin seals, although they had seen two pups swimming with one adult (poor evidence).

CARE OF YOUNG

On Willapa Bay from May to the last of August the mother seal is reluctant to leave the pup. At this season nursing females are easily obtained by the seal hunters who first kill the pup and then wait for the mother to swim within gunshot range. Three informants at widely separated localities told us of seeing small pups riding on the mother's back. Bert Ward stated that when the female slides into the water at the approach of a boat, the pup may follow in her wake and put its foreflippers on her rump. Charles Bearman writes that "it is a wonderful sight . . . to see the mother seal swim around with her baby on the hump of her neck. She then ducks under water and compels the little one to swim. A little squeal, and she heaves up under it. All is well again when it can rest on mother's broad shoulders" (MS). The pup learns to swim in shallow water near the mother. When the pup is tired or when the mother is alarmed by the approach of a boat, she boosts or nudges it and it crawls on her back.

The lightkeeper at Dungeness Spit writes that "when the mother seal gets on the beach and has her young, the tide leaves and the young pups are not able to keep up with her when she hears someone coming. They are easily caught then" (MS).

A pup observed by John Stetson at Copalis Beach, May 29, 1942, 5:00 a.m., was floundering in the surf. An adult seal swimming nearby was apparently trying to help the pup out of its difficulties and Stetson finally was forced to wade in and recover the pup.

A Makah native told us that when the mother dives she may hold the pup with her foreflippers, but when the two come to the surface for air they are usually a few feet apart. Fred Kalso once saw a mother dive with her pup in her mouth and stay under so long that the pup drowned.

The female nurses the young lying on land. We believe that the nursing period extends from 4 to 6 weeks. Of the stomachs of 13 young seals examined by T. H. Scheffer at Nisqually, August 1927, 12 contained curdled milk. On the latest date of observation, August 22, 5 out of 6 stomachs contained milk (1928, p. 15). A seal pup raised recently in captivity was arbitrarily weaned at the end of 2 weeks. Havinga (1933, p. 79) believes that the *Phoca vitulina* of Holland suckles about 6 weeks.

DEVELOPMENT OF THE YOUNG

The condition of the young seal *in utero* was studied in two specimens. A 24-pound fetus (1051 JWS) rested on its back in the uterus with its head pointed toward the mother's rump. The stomach and small intestine of the fetus contained a pale yellow, viscid liquid, and no hairs. The large intestine for 3 or 4 inches inside the anus was plugged with a blackish, thick, greasy, homogenous meconium containing no hairs, and with a pungent, not offensive, greasy odor. The dark mass changed gradually in the adjacent 2 inches to a yellower, softer mass extending for 8 inches in the large intestine and composed almost entirely of packed lanugal hairs. The seal obviously drinks amniotic fluid during the later stages of its fetal life.

On each side of the head of this fetus the ear pinna protruded for a distance of about 5 mm. The lining of the mouth was pink with a few scattered dark spots; the iris dark brown. The claws were more strongly curved and blunter than in the adult. The foreclaws were creamy white beneath and dark brown to blackish above; hindclaws paler.

A second specimen (154 KB), weighing 27½ pounds, was taken 6 weeks

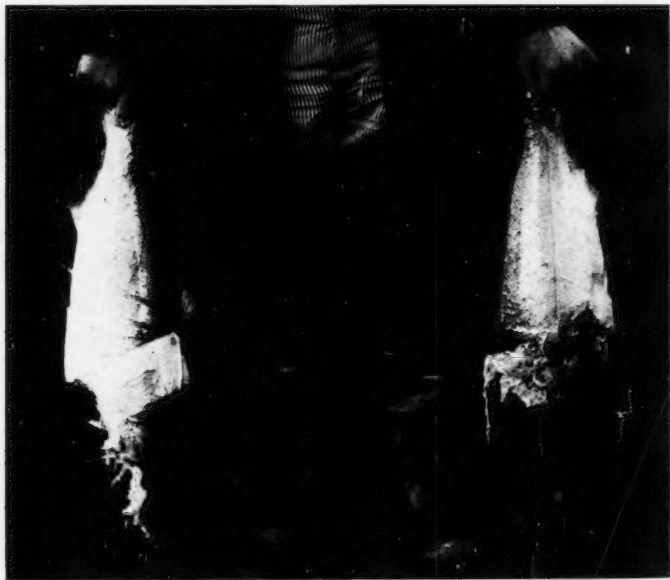


Fig. 17. King salmon (*Oncorhynchus tshawytscha*) mutilated by harbor seals in Skagit Bay, Washington, June 17, 1942. Seals sought out the salmon in gill nets and tore off the head region, leaving the rest of the body hanging. (Photo 1400 VBS).

earlier in the season than the fetus just described although it represents a slightly more advanced stage of development. It bears the spotted coat of the early summer pup. In the uterus, the fetus rested on its back with head directed toward the mother's rump (Figs. 11 and 12). It was covered with loose lanugal hair, and a mass of the hair lay between the hindflippers and the belly. The rectum, large intestine, and caecum were packed with 220 cc. of fetal hair. We cleaned and dried the loose hair that surrounded the fetus and found that it weighed 33.4 grams and could be packed rather tightly into a one-liter container.

The pelage of 6 young seals in various stages of development has been described. Detailed measurements of 2 full-term fetuses and 4 young of the season are shown in Table 2. It seems desirable, by way of summary, to list at this point the salient measurements of the unborn seals and of the early summer young which we have either examined or have had reports of from collaborators. Some of these specimens have been previously mentioned and others are here described for the first time (Table 3).

TABLE 3.—Length and Weight of 11 Fetal and Juvenal Harbor Seals from Washington.

No.	Sex	Date	Locality	Length	Weight
Fetal					
1264 VBS	M	Sept. 12-15	Willapa	103 mm.*	1.27 oz.
1268 VBS	M	Feb. 18	Nisqually	149 mm.*	4.47 oz.
248,402 USNM	F	Jan. 12	Nisqually	405 mm.*	39.0 oz.
1051 JWS	M	July 13	Nisqually	875 mm.	24 lbs.
154 KB	F	May 31	Willapa	910 mm.	27½ lbs.
Juvenal					
1 WW	M	July 15	Grays Harbor	860 mm.	49 lbs.
1120 JWS	M	May 30	Copalis	890 mm.	22¼ lbs.
152 KB	M	May 31	Willapa	890 mm.	19 lbs.**
3 WW	F	July 15	Grays Harbor	905 mm.	46 lbs.
4 WW	M	July 15	Grays Harbor	925 mm.	41 lbs.
2 WW	M	July 15	Grays Harbor	945 mm.	42½ lbs.

* Measured along curve of back, in alcohol.

** Circumstances of the capture suggest that this pup may have gone without food for a time previous to the date that it was recovered and weighed.

Specimens listed in the series "WW" were shot or clubbed by State Fisheries Inspector Wayne Wintermute and weighed and measured 5 hours later by Dr. Kelshaw Bonham.

Great variation in weight among seals of the same length may be noted in Table 3. For example, no. 1041 JWS, a fetus, weighed less than half as much as no. 1 WW, although the fetus was slightly the longer of the two. In explanation, we believe that the nursing pup fattens very rapidly on the rich milk of its mother, a condition that obtains among pinnipeds as a whole. With regard to the localities where these two specimens were obtained, we may say that pups are probably born in Grays Harbor 4-6 weeks in advance of those born at Nisqually.

Insufficient data are at hand to demonstrate the rate of growth of the young seal. To obtain this information it would be necessary to gather a large

number of specimens at all months of the year, or to resort to marking certain individuals and recapturing them. We would venture an opinion, however, that the average pup attains a weight of 50 pounds by the middle of winter and a weight of 50-75 pounds by the end of its first year.

At three intervals we weighed a male and a female pup captured at Nisqually in July and transferred to the Point Defiance Aquarium, Tacoma. Here they had access to all of the fresh or frozen fish that they could eat and were, in other respects also, in a quite unnatural environment. They varied in weight as follows (pounds):

	Male	Female
December 26, 1942	54	54
February 8, 1943	65	70
April 24, 1943	61	65

On the last date shown the pups were fat and well-conditioned but showed little appetite for the frozen fish that had been their diet for the preceding two months.

MATING

We were obliged to terminate our studies of the seal without gaining all of the information that we wanted on its mating habits, particularly as regards the season when mating activity is at its height, and the method of copulation. We believe, however, that copulation is most frequent in September and that it usually takes place in shallow water or on land.

Edward P. Nelson said that on Willapa Bay during the summer he has seen seals apparently in copulation. The act takes place on the sandbars, dog-fashion, lasts about one minute, and is accompanied by fighting (this may, in fact, be fighting rather than copulation).

Dewey Barichio, another professional seal hunter from this bay, had never seen the seals mating. On September 30, 1942, we made a brief visit to Willapa Bay and were told by Barichio that the seals were then "growling on the sandbars" and were believed to be mating.

William Luhr told of stalking a pair of seals about 17 years previous, in the middle of September (?) on Nisqually Flats. Other seals were lying on the adjacent salt marsh, growling and fussing as usual. The female was lying half out of water with her breast against the bank of a slough, on an 8-10 degree slope, at the edge of salt marsh vegetation. The male was astride the female's back with his flippers on her sides. The waves created by the pumping motion of the male first attracted Luhr's attention. He watched the pair in copulation for about 5 minutes before he shot the male.

We had hoped to collect a series of male testes in the summer and fall in order to study the onset and decline of spermatogenesis, but were unable to obtain specimens after July 29. The testes of 4 adults weighing 138-256 pounds reveal that spermatogenesis starts, at Nisqually, in early July.⁴

⁴ We are indebted to Oliver P. Pearson and Robert K. Enders, of Swarthmore College and the Section of Fur Resources of the Fish and Wildlife Service, for examining the preserved genitalia of 7 male and 3 female seals from our collection (MS report, January 14, 1943).

We have no positive data as to the age when the male attains sexual maturity. There is evidence that the female does not mate as a yearling, i.e., in her second autumn and must therefore attain an age of *at least* 2 years before mating and *at least* 3 years before bearing her first pup. The evidence is based on a comparison of the skulls, external characters, and ovaries of female no. 1284 VBS (weight 51 lbs., length 1115 mm., July 8) and female no. 1290 VBS (weight 94 lbs., length 1240 mm., July 14). The first mentioned is certainly a yearling; the ovaries are quite inactive, with no large follicles and no corpora lutea. The second is sufficiently developed to be considered a 2-year-old. Since this female has a virgin uterus she did not mate in the previous autumn. In one of her ovaries there is a very large follicle, possibly close to ovulation.

Havinga states that the *Phoca vitulina* of Holland has a gestation period of 10 months, bearing its young about July 1 and mating about September 1. He believes that the female mates at the end of her third year. Judging from the sudden growth of the *os penis* shortly before this time, he believes that the male also mates at the end of his third year. Havinga deduces from the fact that copulation has not been observed in the seal that it must take place in the water (1933, pp. 79-82).

So far as known, the ratio of sexes is approximately equal. Of 74 seals shot on the Nisqually Flats by bounty hunters in all months of the year, 37 proved to be males and 37 females (Table 1). The males are probably promiscuous in their mating habits; no evidence of a harem structure has been observed.

Brief mention of the sex organs should be made (Figs. 15 and 16). The preputial opening lies about halfway between the anus and the navel. There is an *os penis*, or baculum, which evidently grows throughout the life of the animal. If a large number of bacula could be assembled for study, it might be feasible to correlate the size of the bone with the age of the seal. The measurements of 9 cleaned and degreased bacula in our collection are recorded in Table 4.

TABLE 4.—Size of the Baculum with Relation to Size of the Body.

No.	Age	Entire animal		Baculum	
		Standard lgh., mm.	Weight, pounds and kilograms	Length, mm.	Weight, grams
152 KB	pup	890	19	8.6	35.7
1120 JWS	pup	890	22 $\frac{1}{4}$	10.2	30.2
1292 VBS	pup	891	22 $\frac{1}{2}$	11.3	34.9
153 KB	yearling	1060	79 $\frac{1}{2}$	36.1	33.5
1279 VBS	subadult	1380	-----	-----	97.4
1289 VBS	adult	1395	138	62.6	117.6
1280 VBS	adult	1540	190	86.1	130.0
1282 VBS	adult	1595	131	59.4	134.5
1283 VBS	adult	1700	256	116.1	143.6
					18.8

The testes of the harbor seal are internal (non-scrotal) and lie about 70 mm. apart on either side of the penis, beneath the blubber and outside of the heavy basal muscles of the hindflippers. The testes of 2 large males taken July 1 and July 9 measured, respectively, 30 x 31 x 70 mm. and 31 x 31 x 70 mm. A medium-sized male (1288 VBS) had vestigial mammae, shaped like those of the female but only 2.3 mm. in diameter and 85 mm. apart. An imaginary line connecting the mammae was 90 mm. from the center of the navel. These rudiments appear on the leather side of tanned skins as small but distinct holes.

The vaginal opening of the female adjoins the anus. The ovaries of a large female carrying a late-term fetus on May 31, 1942, measured 12 x 26 x 41 mm.

The two nearly-naked black nipples lie about 100 mm. apart on an imaginary line 100 mm. posterior to the navel. They are usually hidden by the hair of the belly. By probing with a pencil on the blubber side of a fresh pelt we forced the nipples to stand erect to a height of 12 mm. It is likely that the pup, pressing its lips against the mammary gland and sucking, causes the nipples to protrude.

Food Habits

SPECIES EATEN

The harbor seal is known to feed on a wide variety of fish and shellfish, chiefly on those species that are easily captured in shallow water, and to a very limited extent on active forms like the salmon. Some indication of the wide range of diet is given by Table 5, an adaptation of a report by Scheffer and Sperry (1931, pp. 216-222), placed in tabular form by Ford Wilke and the present authors. Results of other stomach examinations are given by Scheffer (1928), but the data are not presented in such a way that they will fit into Table 5.

It should be cautioned that frequency tables, while they serve to indicate the *variety* of foods eaten, are unreliable indicators of the *importance* of the various items in the diet as a whole. Scheffer and Sperry bring out this point and give a summary of the comparative importance, in terms of volume, of the food items in 81 stomachs (1931, pp. 223-226). They report that *fishes* make up 93.58 per cent, *molluscs* (largely squid and octopus) 5.82 per cent and *crustaceans* 0.6 percent of the total volume of the stomach contents. "The average food content of the stomachs was found to be 1.75 pints; the largest meal recorded was 8 pints [six pounds]." Both solitary fish, like the flounder, and schooling fish, like the herring, were taken. In one stomach, 56 herring were found; in another 160 sand launces [locally "candlefish"].

AMOUNTS EATEN

The proprietor of a small saltwater aquarium on the Seattle waterfront told us that a pet 2-year-old male harbor seal consumed about 8 pounds of smelt (*Hypomesus pretiosus*) a day.

Walter H. Chute, director of the John G. Shedd Aquarium, informed us that, while he had not attempted to keep Pacific harbor seals in captivity, he had kept several Atlantic harbor seals for about five years. "These animals were kept in fresh water and fed on fresh water lake herring, of which they

TABLE 5.—Frequency of Items in Stomachs of 81 Harbor Seals from Puget Sound and Other Enclosed Waters of Washington State, December 1927 to August 1930.

Adapted from data of Scheffer and Sperry, 1931. Eleven stomachs in addition to these listed were empty or held only unidentifiable traces of food or parasitic worms.

		Total no. stomachs in which items occurred	Percent of stomachs in which items occurred
Flounders	Pleuronectidae 5	23	28
Pacific Herring	<i>Clupea pallasii</i>	22	27
Tomcod	<i>Microgadus proximus</i>	22	27
Hake	<i>Merluccius productus</i>	18	22
Sculpins	Cottidae 7	17	21
Crabs	Eight species 6 10	15	19
Shrimps	<i>Crago franciscorum</i> and <i>Crago stylirostris</i>	14	17
Squid	<i>Gonatus</i> sp. ⁸	12	15
Pollack	<i>Theragra fucensis</i>	10	12
Shiner, Surf Fish	<i>Cymatogaster aggregatus</i> 11	9	11
Cod	<i>Gadus macrocephalus</i>	9	11
Lingcod	<i>Ophiodon elongatus</i>	9	11
Singing Fish	<i>Porichthys notatus</i>	6	7
Blenny, Snake Eel	<i>Lumpenus gracilis</i> 12	5	6
Rockfishes	<i>Sebastes</i> spp.	5	6
Octopus	<i>Polypus hongkongensis</i>	4	5
Sand Lance	<i>Ammodytes personatus</i>	3	4
Burrowing Crayfishes	<i>Upogebia pugettensis</i> and <i>Callinassa californiensis</i>	3	4
Pacific Lamprey	<i>Entosphenus tridentatus</i>	2	2
Clam	<i>Yoldia myalis</i> 9	2	2
Salmon	<i>Oncorhynchus gorbuscha</i> and <i>Oncorhynchus</i> sp.	2	2
Unidentified Fishes	(Not Salmonidae)	2	2
Silver Perch	<i>Damalichthys vacca</i> 13	1	1
Ratfish	<i>Hydrolagus colliei</i>	1	1
Snail	<i>Trichotropis</i> sp. ⁹	1	1

5 *Hippoglossoides elassodon* identified; also *Parophrys vetulus* (?).

6 *Cancer oregonensis*, *C. magister*, *C. gracilis*, *Hemigrapsus oregonensis*, *Pagurus* sp., *Petrolisthes cinctipes*, *Petrolisthes eriomerus*, and *Pinnixia schmitti*.

7 *Leptocottus armatus* and *Myoxocephalus polyacanthocephalus* identified.

8 In addition to 6 records of beaks retained in folds of stomach.

9 "Probably taken incidentally to the capture of other food."

10 "No doubt many of these small crustaceans entered the seal stomachs as secondary food."

11 We count 9 occurrences listed rather than 11 as stated by Scheffer and Sperry, p. 223.

12 We count 5 occurrences listed rather than 6 as stated by Scheffer and Sperry, p. 224. Dr. Wilbert M. Chapman believes that *L. anguillaris* may have been misidentified as *gracilis*, since the latter is an Alaskan species (letter of October 8, 1942).

13 Given by Scheffer and Sperry as *D. argyrosomus*, p. 223 (Chapman, *op. cit.*).

consumed on an average of five pounds per day (letter of March 13, 1943).

Each of four adult *Phoca v. richardii* in the National Zoological Park, Washington, D. C., were eating about 15 pounds of fresh fish daily in the summer of 1942, according to information supplied by Ernest P. Walker.

With regard to the amount of food taken by harbor seal *pups* we have the statement of Gerald Crowe, formerly of the Point Defiance Aquarium, who received a suckling male pup weighing 20 pounds from Nisqually on July 8, 1942. It was judged from the condition of the umbilical cord to be 4 or 5 days old. For the first 2 weeks it was fed twice daily from a bottle containing one can of undiluted evaporated milk and 2 teaspoonsful of corn syrup. At each feeding 4-5 herring about 6 inches long were forced down the seal's throat. The caretaker was often bitten in the process. When the seal was weaned at the end of 2 weeks it had lost weight, but subsequently regained it. At the end of the third week it was eating nearly all of a ration of 6 dozen 6-inch live herring thrown daily into the water of the tank. The seal caught and ate the fish without assistance.

METHOD OF EATING

Harbor seals in aquaria at Seattle and Tacoma were several times observed eating fish. By skillfully twisting their muscular necks and by throwing their heads sharply from one side to the other they moved the fish about in their mouths as easily as though the food were being handled. We have never seen seals using their flippers to hold fish.

We watched a seal struggling with a red-meated salmon weighing perhaps 10 pounds, in shallow water off Dash Point, August 22, 1942. The action required about 30 minutes before the fish was reduced to about 3 pounds and the seal swam away. Our attention was first drawn by loud splashes and snuffing noises as the seal shook the fish in its mouth, awkwardly because of its size. The seal worried and bit the fish, often releasing it and grasping it again from a submerged position. On one or two occasions we plainly saw (through binoculars) the seal swallow a bite of meat. The fish was often held half or entirely out of water, crosswise in the seal's mouth, at first with considerable struggling.

The dentition of the seal shows that the teeth are used primarily for seizing and tearing the food, to a minor extent for grinding it. The teeth of adults are generally clean and sharp, with little evidence of wear. The tip of the tongue has a peculiar V-shaped notch about 6 mm. deep, its function unknown. (The tongue of the Steller sea lion has a similar notch).

It is evident that seals do not, in capturing food, depend entirely upon their vision, for they commonly hunt in river waters that are heavily charged with mud. Fred Kalso, vertebrate seal hunter, reported that he once shot a blind seal that appeared to have had no trouble in gaining its livelihood. Old scars on its head indicated that it had been blinded by a charge of shot; the hair had grown over the sockets so as nearly to obscure them.

Economic Status

The harbor seal is considered a nuisance in certain waters and an interesting part of the native fauna in others. In the vicinity of river mouths where commercial fishermen concentrate and near hatchery traps the seal population should be kept to a minimum by hunters employed on a salary basis on public funds. Where practicable, the bodies of seals killed under such circumstances should be recovered, the skins preserved for commercial use and the carcasses utilized as food for animals. Furthermore, until we know a great deal more about the natural history of the seal than we do at present, important parts of the bodies of seals killed, together with field notes, should be preserved for study by biologists. In waters that are not intensively fished the seals should be left strictly alone.

Blame for the decline in a local fishery is often directed at the harbor seal whereas it rightfully belongs to selfish or thoughtless practices of man, such as overfishing, the damming of streams, pollution by industrial wastes, and so on. It has long been the opinion of the authors that the proper time to control the native predators of fish is *after* satisfactory control of shortsighted human practices has been effected. Such public attention as is attracted by the clamor of persons who would slaughter seals on a wholesale basis often detracts a corresponding amount of notice from the objective where it rightfully belongs, namely, evils of outlaw fishery practices.

We have not spent sufficient time on the problem of the seal *versus* the salmon to be able to evaluate quantitatively the impact of the Washington seal herd upon the fishery. We have, however, had reports from so many sources and over so many years that we are inclined to believe that the gillnetters are justified in their demands for seal control. State fisheries biologist Lloyd Royal and the writers estimated, in April 1942, that there were 1000 seals in Willapa Bay. During the summer months some 24 gillnet boats are operated here, mostly by individuals. The nets are put out at nightfall, allowed to drift with the tide in 20-30 feet of water for as long as one hour, then "picked." There are 5 or 6 pickups a night. The seals learn to slip in quietly in the dark, seize a salmon, and disappear. Elmer O. Pedersen told, on one occasion, of picking 13 salmon of which only 2 were worth keeping, the rest having been mutilated by seals. Seals may take the whole fish but usually only the fleshy visceral region, leaving the head, back, and tail. The greatest damage occurs during August and September. Pedersen believes that seals take silver and king salmon in preference to dog salmon.¹⁴

On June 18, 1942, we visited the important gillnet port of La Conner, at the mouth of the Skagit River, and went out in the early dawn with the boat that picked up the catches of the individual fishermen. The total catch on the preceding night was 800 pounds, including 31 king salmon and 1 sockeye.

¹⁴ The seeming preference of harbor seals for red-meated salmon is pointed out by Ernest P. Walker (1917, p. 48). This investigator studied the damage to salmon by seals at the mouth of the Stikine River, Alaska, May 1915, and found that, of 1184 red-meated king salmon taken in nets visited, 27 per cent had been mutilated by seals; while of 278 white-meated salmon, 9 per cent had been mutilated.

Two salmon that had been torn by seals were recovered (Fig. 17). By matching the remains with fish of known weight we were able to estimate the original size of the damaged specimens. No. 1: original weight 35 pounds, weight of remains 14 pounds, fisherman credited by buyer with 10 pounds; loss in value 25 pounds (at $18\frac{1}{4}$ cents a pound), or \$4.56. No. 2: original weight 20 pounds, weight of remains 16 pounds, fisherman credited with 10 pounds, loss in value 10 pounds or \$1.82. When it is considered that 1 or 2 fish frequently constitute the entire night's catch of a fisherman, the loss of a single fish to seals is an important matter.

Scheffer (1928, pp. 14-15) found salmon in 2 out of 14 adult stomachs containing food. One stomach contained a silver salmon with "tail, pelvic girdle, fins, and large pieces of skin and flesh still intact" [weighing 9.07 pounds.] Another contained "flakes and parts of the spinal column of three small fish of the salmonoid type less than a foot in length." Scheffer and Sperry (1931, pp. 221-222) found salmon in 2 out of 81 adult stomachs containing food. One contained remains of a salmon 12-14 inches long, the other "parts of a large fat salmon."

The stomach of a seal collected by Milner B. Schaefer in Harrison Lake, B. C., September 21, 1941, was examined by Ford Wilke. The contents included parts, or entire bodies, of four humpback salmon, together with about 450 nematode worms; total volume 1730 cc. The seal was taken in the vicinity of a fish hatchery trap (MS).

Aside from its relation to the fishing industry the harbor seal has other commercial importance. The flesh, viscera, and hide have long been used by west coast Indians, according to Swan (1869, p. 30) and Gunther (1936, p. 116). The Indians now living on the coast at Lapush dry the skins flat, i.e., open, with the flippers cut off near the body. The flesh is dark red and bloody, perhaps a bit more palatable than sea lion but less so than fur seal. It is nearly always boiled, seldom fried.

A Seattle furrier told us that harbor seals are occasionally made into jackets. "Ninety-nine" per cent of them are dyed brown or black. Almost invariably the small ones, requiring 6-8 skins per jacket, are used because of their thinner leather and lighter weight. Only two large skins are required for a jacket. Alaska supplies most of the skins.

Hundreds of skiers in the Pacific northwest use strips of seal skin, hair pointing backward, fastened beneath their skis while climbing hills. The hair does not especially impede forward motion but it keeps the skis from slipping back.

Fred Kalso of Bay View, Washington, reported that in 1923-24 he sold the skinned carcasses of 31 seals totalling 3400 pounds, to the Vendovi Island Fox Farm (T. H. Scheffer, MS). A resourceful person at Anacortes uses seal meat for mink food and sells the roughly-cleaned skeletons to schools and colleges for demonstration material.

A few studies have been made of the oil content of Pacific harbor seals. Brocklesby states that:

"On the British Columbia coast, hair seals are a menace to the fishing industry, causing considerable damage to fishing gear and destroying large numbers of salmon. During recent years a bounty has been paid for their destruction, but the number captured has not, up to the present, warranted their utilization in oil manufacture. . . .

"Seal and sea-lion blubber oils have much the same properties as whale blubber oils. . . . They have been used as adulterants for cheap paints. . . . They have been used for the manufacture of certain types of soft soaps, for the preparation of chamois by the French method and also in the compounding of lubricants. . . . The vitamin potencies of these blubber oils are too low to warrant their utilization as animal feeding or medicinal oils" (1941, pp. 418-419).¹⁵

Brocklesby gives the following estimate of the vitamin potency of *Phoca vitulina richardii* (op. cit., Table 12):

Source of oil	Per cent oil	Vitamin A (B.U./g.)	Vitamin D (I.U./g.)
liver	2-4	8,000-10,000	20-40
blubber	80-90	40-50	20-40

We found that the fresh liver of a 190-pound male seal killed July 1, 1942, weighed 5½ pounds.

REFERENCES

- ALLEN, JOEL ASAPH. 1880—History of North American pinnipeds, a monograph of the walruses, sea-lions, sea-bears, and seals of North America. Washington, Govt. Printing Office, 785 pp.
- 1902—The hair seals (family Phocidae) of the Pacific Ocean and Bering Sea. Bull. Amer. Mus. Nat. Hist. 16:459-499.
- BENCHLEY, BELLE J. 1937—Old timers. Zoonoos 4(23):1-4.
- BONHAM, KELSHAW. 1942—Records of harbor seals in lakes Washington and Union. Seattle. Murrelet 23(3):76. (Feb. 15, 1943).
- BROCKLESBY, H. N. 1941—The chemistry and technology of marine animal oils with particular reference to those of Canada. Fish. Research Board of Canada, Bull. 59:1-442.
- CLARK, J. W. 1873—Exhibition of, and remarks upon, skulls of *Phoca (Halicyon) richardii* and *Phoca vitulina*. Proc. Zool. Soc. London 1873:556-557.
- DOUTT, J. KENNETH. 1942—A review of the genus *Phoca*. Ann. Carnegie Mus. 29:61-125.
- GRAY, J. E. 1864—Notes on seals (Phocidae), including the description of a new seal (*Halicyon richardii*), from the west coast of North America. Proc. Zool. Soc. London 1864(1):27-34, and, Ann. and Mag. Nat. Hist. ser. 3, 14:304-311.

¹⁵ Harbor seal oil is not a standard commodity. By way of comparison, however, it is interesting to note that Alaska fur seal oil sold in Seattle in 1942 for 61.6 cents a gallon.

- 1874—Hand-list of seals, morses, sea-lions, and sea-bears in the British Museum. (London, Trustees of the British Museum), 44 pp. 30 plates.
- GUNTHER, ERNA. 1936—A preliminary report on the zoological knowledge of the Makah. Essays in Anthropology in Honor of Alfred Louis Kroeber, Univ. California Press, pp. 105-118.
- HAVINGA, B. 1933—Der Seehund (*Phoca vitulina* L.) in den Holländischen Gewässern. Tijdschr. Nederland. Dierk. Vereeniging ser. 3, 3(2-3):79-111.
- HENTSCHEL, E. 1937—Naturgeschichte der nordatlantischen Wale und Robben. (In Handbuch der Seefischerei Nordeuropas). Stuttgart 3(1):1-59.
- HOLLISTER, NED. 1925—Annual report of the National Zoological Park for 1923. (In Ann. Rept. Smithsonian Institution 1923, Washington, D. C.)
- HOWELL, A. BRAZIER. 1929—Contribution to the comparative anatomy of the eared and earless seals (genera *Zalophus* and *Phoca*). Proc. U. S. Nat. Mus. 73: 1-142, pl. 1.
- 1930—Aquatic mammals, their adaptations to life in the water. Charles C. Thomas, Publisher, Baltimore 338 pp., illus.
- SCHEFFER, T. H. 1928—Precarious status of the seal and sea-lion on our northwest coast. Jour. Mamm. 9(1):10-16.
- SCHEFFER, T. H., AND CHARLES C. SPERRY. 1931—Food habits of the Pacific harbor seal, *Phoca richardii*. Jour. Mamm. 12(3):214-226.
- SCHWARZ, ERNST. 1942—The harbor seal of the western Pacific. Jour. Mamm. 23(2): 222-223.
- SWAN, JAMES G. 1869—The Indians of Cape Flattery.... Smithsonian Inst. Gen. Pub. 220:1-108.
- WALKER, ERNEST P. 1917—Destructiveness of hair seals in the salmon fishery. (In Alaska Fisheries and Fur Industries in 1915). App. III, Rept. U. S. Comm. Fish. 1915, Bur. Fish. Doc. 834:47-51.
- WEBER, MAX. 1927—Die Säugetiere. Jena, Gustav Fischer. 1:444 pp.; 2:898 pp.

UNITED STATES FISH AND WILDLIFE SERVICE,
SEATTLE, WASHINGTON.

Observations on the Nesting Mortality of the Brewer Blackbird, *Euphagus cyanocephalus*

Ira La Rivers

Locality Studied

The observations reported in this paper were made during the spring of 1934 on the Brewer blackbird population of a 15-acre tract of chaparral and forest 14 miles northwest of Reno, Nevada. The period of observation, extending from May 17 to June 16, was preceded by a four-day examination of the area in an effort to locate and map the positions and contents of all nests (Fig. 1). During this provisional checkup, 91 nests were discovered, 42 being in various stages of construction, while many of the remainder had been finished so recently that they contained no eggs. During the following week—May 17 to 24—15 more nests were found. Nest No. 107 was not located until the 27th. This figure of slightly more than 7 nests per acre indicated a heavy infestation for the region.

The zonation of the area is of interest because of its truly transitional aspect, lying as it does at the junction (as nearly as zonal junctures can be postulated) of Transition and Upper Sonoran life zones, on the lower, northwestern slopes of Peavine Mountain (Fig. 2). Southeast of the area studied, the slopes and ridges ascend to Peavine Peak, 8,270 feet high, while directly north lies Dry Lake, a symmetrical playa occupying the lowest point of adjacent Lawton Valley, at an elevation of 5,000 feet. The blackbird plot discussed here lies at an elevation of 5,500 feet, and is dominated by Transition floral elements, most prominent of which are Mountain Mahogany (*Cercocarpus ledifolius*), Jeffrey Pine (*Pinus ponderosa jeffreyi*), White Fir (*Abies concolor*), and Incense Cedar (*Libocedrus decurrens*) (Fig. 3). Intrusive Upper Sonoran elements are represented by Sagebrush (*Artemisia tridentata*), Wild Peach (*Prunus andersoni*), Buckbrush (*Purshia tridentata*), and Serviceberry (*Amelanchier alnifolia*), the latter being characteristic of the Transition—Upper Sonoran zonal juncture. Buckbrush, an inhabitant of the extreme upper limits of the Upper Sonoran, is a consistent indicator of the proximity of the Transition, and in this region fringes the Jeffrey pine forest. Mountain Mahogany extends considerable distances from the pine stands, and is regarded, in this study, as the Transition zone index species, for it makes a sharper unit contact with the Upper Sonoran than any other Transition element.

Initial observations began on May 13, at which time the nesting season was well under way, and continued for a month, during which time all surviving eggs had hatched, and the birds matured enough to leave the nest. In order to tabulate results more conveniently, check data, and formulate conclusions, the tract of 15 acres was divided into four divisions, East, West, Coyote Spring, and Meadow, lying, respectively, east, west, south, and north of the centrally-located cabin which the author occupied during the study.

Mortality Factors**A. BIOLOGICAL FACTORS**

The problems confronting any bird with a nest are many. Of greatest importance is the effect of the surrounding animal population, which normally

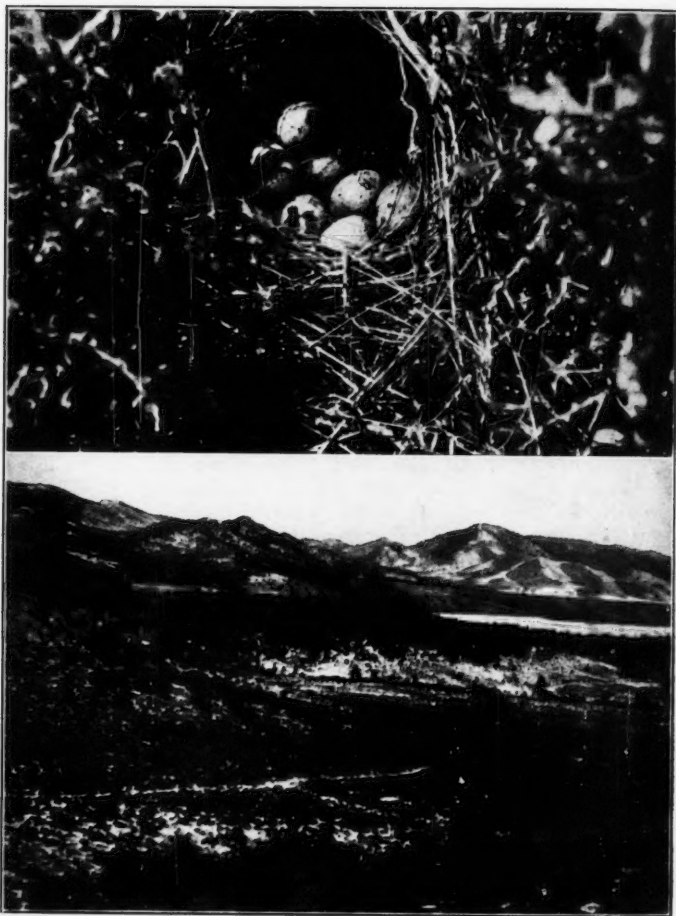


Fig. 1, upper. A typical nest of the Brewer blackbird situated deep in the center of a large sagebrush (*Artemisia tridentata*).

Fig. 2, lower. General winter view of the region studied. The distinct contact between Transition and Upper Sonoran zonal elements shows in the centerground.

is responsible for the greatest destruction of birds, eggs, and nestlings, while physical agencies, such as wind, rain, and extreme temperature fluctuations, account for the remaining loss.

The total mortality of 521 eggs laid in the plot amounted to 60.65%. Biological factors were responsible for 86.07% of this damage, predation, of course, being pre-eminent. In analyzing the importance of predation upon the bird population, the author found it convenient to reduce the factors to their component parts: these were found to include (1) predators who were persistent bird and egg feeders during the nesting season, such as *Aphelocoma californica* and *Pica pica hudsonia*; (2) predators who could only be classed as occasional opportunists, such as *Citellus mollis* and *Citellus grammurus beecheyi*; (3) animals which were accidental causes of nest mortality, such as was witnessed in the cases of *Erethizon epixanthum* and *Equus caballus*; and (4) the human element. Admittedly, it is difficult, in many cases, to draw the line between (1) and (2), and even if a particular predator is conclusively established to belong to one or the other of these categories in any particular survey, it does not follow that the animal will play the same role in a similar study elsewhere.

1. *Primary Predation.*—To this group of predators belong the following: *Aphelocoma californica*, *Pica pica hudsonia*, *Corvus brachyrhynchos hesperis*, *Mustela frenata nevadensis*, *Bassariscus astutus raptor*, *Pituophis catenifer deserticola*, *Coluber taeniatus*, and *Coluber constrictor mormon*.



Fig. 3. A group of trees representative of the area. A. A willow (*Salix* sp?) at the edge of the scene; B. Jeffrey pine (*Pinus ponderosa jeffreyi*); C. Incense cedar (*Libocedrus decurrens*); D. Quaking aspen (*Populus tremuloides*); E. White fir (*Abies concolor*).

Apelocoma californica, the California jay (7.52% biologic destruction, 9.21% predation, 13.46% primary predation).¹ This bird was a significant factor in the predatory picture, and was credited with destroying 14 eggs and nestlings in the blackbird colony. However, of the 83 eggs and nestlings which disappeared without apparent cause, it is impossible to estimate how many the California jay was responsible for, as is the case of all the other predators involved.

The hunting jay, a sly, quiet, and inconspicuous bird, foraged silently through prospective bushes and chaparral with an efficiency that made it a formidable enemy of the nesting blackbirds. Most of the jays for which the author has records were found taking eggs or nestlings from nests from which the parents were absent, but I noted one crusty individual who drove the distraught female blackbird from her eggs (Nest 62). The actions of the blackbird attracted my attention as I was coming through a small grove of Jeffrey pines. She was calling hoarsely and flitting erratically about above the sagebrush in which the nest was located, and attempting to drive the jay away by repeated dashes over him. Each time the blackbird flew close, the jay quickly faced about threateningly, and the attacker veered off. Once she darted upon the jay and almost caught him off guard; startled, he flew up from the nest, alighted on a branch a few feet distant, then dropped down to his meal again. At this point, the male blackbird arrived, and both birds dove at the jay. In the face of this, the predator dropped quickly over the side of the bush and flew swiftly away a few inches above the ground, noisily pursued by both birds, the female soon returning to the nest, while the male continued the chase until both were out of sight.

Twice the returned bird settled down as if to brood, after initially busying herself with a thorough inspection of the nest, then immediately hopped to the edge, faced inward, and looked the nest over. She dropped a few pieces of broken shell over the edge, and cleaned some of the spilled egg contents by jabbing her bill into them, then shaking the material off at the edge of the nest. More inspection followed, after which she flew to the ground, gathered up several short, stubby twigs, and placed these in the nest.

Not wishing to disturb her further, after so strenuous an half hour, and so run the risk of driving her from the locality, I went quietly away. Two hours later, I found her still sitting contentedly on her eggs. She was alert as I came up, and watched me with more than the usual apprehension. Nevertheless, I advanced as slowly as possible in order to drive her gently from the nest. She allowed me to approach to within ten feet, then flew off and alighted on the ground some twenty feet away; I found but two of the original five eggs left, and fragments of some of the broken eggs still in the nest. The twigs I saw her gather (and about which I was most curious) were arranged loosely in the bottom, where the contents of some of the broken eggs had oozed over the fibers, soaking them thoroughly. Her only purpose in bringing these twigs,

¹ The percentages for biological destruction, predation, and secondary predation are obtained by dividing the number of destroyed eggs and/or nestlings accredited to the particular species in question by the total number of destroyed eggs and/or nestlings tabulated for the particular subdivision under discussion.

as near as I could determine, was apparently that of covering the wet portion of the nest so she could brood more comfortably. She returned as soon as I began to walk away.

The typical behavior of a jay surprised while raiding a nest from which the mother bird was absent was that encountered at Nest 10. The bird had torn up the nest quite a bit while rummaging through it, and had scattered the shell fragments over the nest and the ground below. When I appeared, he slipped over the edge, and disappeared in the brush.

Pica pica hudsonia, the American magpie (13.44% biologic destruction; 16.44% predation, 24.03% primary predation). The magpie is reliably credited with the destruction of 25 eggs and nestlings in the colony. Like the preceding species, the magpie is strikingly quiet while hunting and was apparently more of a problem to the nesting blackbirds than the jay, although it must be conceded that the jay, because of his drabber plumage, could go unnoticed where often the magpie's white-and-black would be readily discovered. This fact may account for the latter's apparent greater destruction.

The actions of the magpie at Nest 19 were typical. This nest, built four feet below an occupied *Turdus migratorius propinquus* nest, was discovered by a *Pica* eight days after I had found it while surveying the area. I arrived in time to see him as he was finishing the meal of six blackbird eggs, and frightened him away. Flying up into the highest branches of an adjacent Jeffrey pine, he waited expectantly while I looked into the nest and found two badly broken eggs whose contents were oozing out, and the depleted shell fragments of the remaining four. The female blackbird was nowhere in sight, so I retreated to watch the magpie. Hiding behind a distant pine tree was not sufficient to trick the attentively-silent bird into returning to the nest, and he contented himself with hopping nervously about in the top of the tree, stubbornly refusing to descend any closer to the eggs he wanted so badly. After twenty minutes of this, I beat a full retreat, walking away out of sight. Returning quietly a half hour later, I found him again busy in the nest. He flew up immediately, and disappeared in the dense chaparral. This time I found he had cleaned the nest, and, as I turned to leave, a blackbird flew furtively off low over the chaparral from an adjacent clearing. Perhaps the mother.

In one instance, three magpies attacked a single nest. For several days, a small band of the birds had been frequenting the vicinity, and I came upon three of them at Nest 91 one day while I was making the rounds. They flew heavily away, and all that remained of the five nestling were some bits of still-warm intestine and a foot. This nest, which originally contained seven eggs, had been visited previously by a California jay, who took two eggs.

Corvus brachyrhynchos hesperis, the Western crow (4.30% biologic destruction, 5.26% predation, 7.69% primary predation). Crows were not numerous in the vicinity, and the eight eggs and nestlings traceable to this species seemed to have been the work of one individual whose normal hunting range was in the meadowlands adjacent to the west.

Approaching Nest 53, I caught a crow, a rather small individual, in the

act of devouring the last egg. As was often the case, the parent blackbirds were nowhere in sight, and the crow flew off unmolested. The nest had one side completely torn out, probably the result of the large bird's attempt to balance on the edge of the frail structure. Fresh egg fragments were strewn about.

Mustela frenata nevadensis, the Nevada bridled weasel (6.45% biologic destruction, 7.89% predation, 11.53% primary predation). Most of the weasels' activities were directed towards the nesting birds, rather than their eggs; in fact, the only evidence found that this species may have taken eggs was at Nest 96. Weasel tracks were abundant in the soft, damp ground about the bush, and the fresh shell fragments of the four eggs were still in the nest. The mother bird was not to be found, so it seems unlikely that she had been killed by the weasel.

Nest 98 was more typical of this predator's depredations. Here I found the brooding bird lying at the base of the Jeffrey pine tree (in which the nest was built) with her skull broken through at the back, and most of the brain cavity emptied. Weasel tracks leading up to the pine needle mat under the isolated tree left no doubt as to the predator. The seven eggs of the nest died from the cold, and remained in the nest until the structure began to disintegrate.

Bassariscus astutus raptor, the Western ringtail (6.45% biologic destruction, 7.89% predation, 11.53% primary predation). The discovery of this species in the vicinity was a surprise. Like the preceding weasel, the ringtail apparently preyed only upon the adult blackbirds.

The first indication that this species was an inhabitant of the region came at Nest 81 one evening. Returning to the cabin about 8:30 one dark, starlit evening, a disturbance was heard among the nesting blackbirds at the edge of the forest. I followed the sound, but the tumult had largely died down when I had covered the 200 yards to the approximate vicinity, and the blackness of the night gave no clue as to the source of the disturbance. The nesting birds, of which there were six in the immediate vicinity, were still moving about restlessly. I sat down and waited for twenty minutes, but by that time all was quiet, so I left.

Returning the following morning, small cat-like tracks were to be seen on a clear spot between two large pine trees. Nothing more was seen that day, but in the evening, I left for the spot a little earlier with a bullseye lantern, and approached so slowly and cautiously that it took approximately 20 minutes to cover the last 300 yards, utilizing the thick Mountain mahogany chaparral as cover. My coming did not disturb any of the birds, and I settled down behind a large mahogany 20 yards from the tree which had been the center of the preceding night's disturbance. For what must have been half an hour, nothing stirred, except an occasional blackbird. Once or twice the hunting call of a distant horned owl was heard and was followed by momentary stillness.

Suddenly a nesting blackbird off to my left began a commotion. Immediately the remaining birds took up the sound. I tried to edge closer to the

initial disturbance but in my anxiety to discover what was going on, I scared a nearby blackbird from her nest, and the entire group was in an uproar. A peculiar, throaty squawk was issuing off to my left, in the same direction as the original sounds, and I decided to risk the lantern. The light snapped on, and I swung it in the desired direction. The nest (81) which, from the sounds, I had judged to be the one involved, was empty. I moved the beam around without seeing anything, then stopped it on two blazing eyes that flashed into view. Peering around the bole of a middle-sized pine tree, some ten feet above the ground, was a tiny, raccoon-shaped face, with large, erect ears rigidly alert. Only for an instant did the animal look into the light. He backed away, turned deftly, and disappeared. In the second I saw him, I puzzled at his identity, but the minute he turned, from the opposite side of the tree a black and white-ringed, bushy tail swept into view. I ran to the tree and turned the light frantically among the foliage, but the platform at the junction of two branches and the trunk, where he had been standing, was deserted, as were the surrounding trees. At the foot of the tree lay the still-warm body of the brooding bird of the attacked nest, the neck crushed and broken by sharp, powerful teeth.

Returning the following morning the eggs were still in the nest, but chilled and cold. From then on they gradually disappeared, and the nest fell into ruin.

Pituophis catenifer deserticola, the Desert bullsnake (2.68% biologic destruction, 3.29% predation, 4.80% primary predation). This very common snake was largely an habitué of the fields and open brush lands adjacent to the blackbird plot to the north and northeast, but several individuals hunted persistently within the blackbird colony.

Nest 3, built four feet above the ground in a serviceberry bush, was raided by a large bullsnake. A week after initial discovery of the nest, I was attracted to the scene by the antics of the parent birds, and hurried over in time to disturb the snake, which I had not intended to do, and he slipped to the ground and disappeared. The anxious birds had none of the boisterous cocksureness of their kind about them this time, but jumped rather pathetically about in the upper branches of the bush, silent for the most part, as if they realized the futility of attempting to frighten or fight so formidable an enemy.

In another instance, I accidentally saved the contents of Nest 39 from a bullsnake. Oblivious to all but my own thoughts, I passed this securely-hidden nest with no intention of looking in, for I had just inspected it two hours before. As I came abreast of it, I heard a snap and rustle of branches, and looked up in time to see the snake drop to the ground and whip away through the underbrush. The brooding bird was not to be seen, and I found an egg missing from the nest.

Coluber taeniatus, the Striped racer (5.37% biologic destruction, 6.57% predation, 9.61% primary predation). This reptile was less abundant than the other three species of reptiles, and was responsible for a total of ten eggs and nestlings.

Coluber constrictor mormon, the Mormon racer (5.37% biologic destruc-

tion, 6.57% predation, 9.61% primary predation). The Mormon racer was next in abundance to the bullsnake.

Nest 25 provided the most complete observations on the activities of the racer. While making the periodic circuit of the East Division nearly two weeks after the beginning of this study, I saw, from a distance of some 30 yards, the parent birds dancing about in the air above their nest; fitfully, they dropped swiftly towards the bush, veered upwards, and repeated the performance, shrilling excitedly the while, and often standing motionless in the air on beating wings before diving towards the nest. I approached with caution, which I need not have exercised on their account, for they were totally absorbed. And, like the birds, the snake was absorbed in his work. It was a study in repto-avian moods, and I became as preoccupied as the principals.

The birds continued their unavailing efforts to route the snake, but the latter hardly seemed to notice them, except when they, made bolder perhaps by the racer's disregard, swept closer than usual, at which he raised his head and peered intently in their direction. At this motion, the birds immediately veered away. Occasionally, they rested on a twig of the same bush a foot away from the snake, anxiety in every feather, and shrill whistles alternating with hoarse throaty calls.

Suddenly, after an interval of nearly four minutes, the snake slid swiftly to the ground along the trunk of the bush and made off in a northeasterly direction. Immediately both birds, who had been resting on a branch of the bush, darted down in pursuit. They resembled nothing more, now, than little black hawks. Although neither could have done the reptile any conceivable harm, they now dashed fiercely at it. Each time one of the birds dropped close over the fast-moving snake, who was on more-or-less open ground traveling across the head of a tiny meadow whose grass was extremely short and sparse, the racer either darted ahead more swiftly, or stopped suddenly, throwing his head and forebody back out of the way in a defensive "S" loop. Once or twice he merely raised his head high off the ground, never slackening the pace. The enraged birds made six sallies at the slender racer before the latter gained sanctuary in the sagebrush some 30 feet away, whence they returned to their nests. The female bird investigated the structure thoroughly, still apparently unaware of my presence then, after a moment or two, flew off, followed by the male. Looking in the nest, I found a lone egg fragment. Two days before, the nest had contained four newly-hatched young and two eggs. Undoubtedly these last two had hatched in the interim, and all but the fragment I found had been removed by the brooding bird. Both birds abandoned the nest, and it remained unoccupied the remainder of the season.

2. *Secondary Predation*.—To this group belong the following species: *Accipiter velox*, *Bubo virginianus pallescens*, *Cyanocitta stelleri frontalis*, *Citellus mollis*, *Citellus grammurus beecheyi*, *Callospermophilus chrysodeirus*, *Sciurus douglasii*, *Mephitis mephitis major*, and *Crotalus viridis lutosus*.

Accipiter velox, the Sharp-shinned hawk (2.68% biologic destruction, 3.24% predation, 9.43% secondary predation). While I did not see this incident, the death of the bird brooding Nest 21 was so clearly the work of this

species, that I have no doubt as to the interpretation. While wending my way through the chaparral, I saw a Sharp-shinned hawk rise into the air a few yards ahead of me and disappear in the thick pine forest. Rounding the Mountain mahogany in my path, I found the fresh remains of the blackbird lying on the ground near the base of the tree. She had evidently been attacked either when approaching or leaving the nest. The eggs subsequently chilled and died.

Bubo virginianus pallescens, the Western horned owl (2.15% biologic destruction, 2.63% predation, 8.33% secondary predation). I know of but one reasonably authenticated instance in which the horned owl can be justly claimed to have taken a nesting blackbird, although, from the prevalence of owls in the neighborhood, it is reasonable to suppose that some of the unaccountably missing nesting birds must have fallen prey to this predator also. In this instance, I had visited Nest 85 late one afternoon and found the female brooding the four nestlings. Chancing by the following morning on my way to Cody Basin, I noticed the nest was partially torn down, and three dead nestlings lay on the ground below. A few rods away, some fresh blackbird remains and feathers showed where the parent bird had been eaten. The spot was near an old tree stump, neatly hidden from the clearing in which the nest lay, by a small but thick growth of Incense cedar, which was a favorite spot for one or more horned owls, as attested by the large numbers of fresh pellets about the base of the stump.

Cyanocitta stelleri frontalis, the Blue-fronted pine jay (2.15% biologic destruction, 2.63% predation, 8.33% secondary predation). But one instance was discovered of this not uncommon bird robbing a blackbird nest. The nest (99) was built four feet from the ground on an outer, exposed branch of a small White fir tree. Coming suddenly through the surrounding trees, mostly small, recent growth Jeffrey pines, I frightened the pine jay from the nest, which he almost tore down in flying away. The nest contained fragments of a shell, while other bits lay on the ground below. As so often seemed the case, the parent birds were not to be seen. In attempting to determine the primary causes of mortality in cases such as these, it has not been forgotten that animals found feeding on blackbird eggs when the parent birds were absent might very well be merely opportunists who chanced by, and took advantage of the desertion. It is quite possible that another predator may have recently killed the brooding bird in which case any animal arriving later and eating the eggs could not justly be designated as the cause of the nest's failure. These opportunists are, for the most part, species who would not, under normal circumstances, attempt to attack an occupied nest.

Citellus mollis, the Piute ground squirrel (2.68% biologic destruction, 3.29% predation, 10.41% secondary predation). A very common ground squirrel in the sagebrush portions of the area.

Nest 95 was built, unhappily for the owners, in a medium-sized sagebrush growing in the middle of a colony of Piute ground squirrels. So, when eggs began to disappear systematically, two days after being laid, I was fairly certain whom to suspect; although, until such depredation was actually witnessed,

it might also be ascribed to either *Pituophis catenifer deserticola* or *Coluber taeniatus*, among others. The second day after the depredations began, I caught the culprit. Beside the entrance to one of the squirrels' burrows, I found some fresh eggshell fragments. That afternoon, approaching the bush cautiously, I frightened a squirrel from the lower branches, and he immediately dropped to the ground and darted into a burrow. The nest was empty this time, and shell fragments were scattered about the base of the bush.

Citellus grammurus beecheyi, the Beechey ground squirrel (6.45% biologic destruction, 7.89% predation, 25% secondary predation). These ground squirrels were common, especially in the northern and northeastern sections of the colony, where sagebrush predominated. Nest 14 provided the most instructive example of the species' activities.

Two squirrel burrows occupied the base of the small Mountain mahogany in which the nest was built. Soon after the initial discovery, I surprised a large squirrel in the act of descending the bole of the tree with a blackbird egg clutched between head and one forepaw. In his scramble to get to the ground when he saw me, he dropped and broke the egg. Neither parent bird was in sight. I held small hope for the nest, but, as circumstances had it, it was saved from further inroads by a large badger (*Taxidea taxus*), who dug up both squirrel borrows and ended their menace to the blackbirds. Two days after frightening the squirrel from the nest, I passed by and found one of the squirrel burrows freshly dug out. The following morning, shortly after day-break, I chanced upon a large badger digging desultorily in a pit a few feet from the tree, while the brooding female, now much in evidence, perched anxiously on a branch a few inches from the nest. I waited, far enough away to be inconspicuous, until the badger left.

Callospermophilus chrysodeirus, the Sierra mantled ground squirrel (2.68% biologic destruction, 3.29% predation, 10.41% secondary predation). These ground squirrels were common in the forested portion of the area studied, but rarely attempted to climb into bushes or trees.

Nest 71, constructed three feet from the ground in a small Mountain mahogany, was victimized by an ambitious Golden mantle. I approached the nest through a growth of small, young pines, forewarned by cries of the parent birds. Apparently surprised in the act of robbing the nest, the squirrel had grasped an egg and started for home as fast as his sturdy little legs could carry him. When I first saw him, he was attempting to negotiate the short distance to the ground, grasping the small, rough tree bole with three legs, and hugging the much-too-large egg to his breast with a foreleg. Why he prized the egg so highly, I do not profess to know, but he must have deemed it important booty, for he clung to it tenaciously. The squirrel was decidedly handicapped, however, for the angry blackbirds were striving vigorously to penetrate the closely-set branches and profuse leaves in an effort to do what they could in the way of harm to the adamant raider. When the squirrel was only a few inches above the ground, the male blackbird found an opening, and darted at him furiously. Taken completely by surprise, the squirrel attempted to dodge, lost his footing, and fumbled the egg. Squirrel, blackbird, and egg

tumbled to the ground, the frightened mammal rolling to his feet and making off with all his energy. The birds darted after him, the female giving up the chase almost immediately to return to the nest. No attention was paid the fallen egg by either bird, and I left. Returning three hours later, I found the egg still on the ground, and the female brooding contentedly. She flew up as I came to the tree, and I stayed only long enough to examine the egg. It was cracked, so no attempt was made to replace it in the nest.

Sciurus douglasi, the Douglas chickaree (6.45% biologic destruction, 7.89% predation, 25% secondary predation). This species was the common tree squirrel of the vicinity, and two individuals seemed to have developed a decided liking for blackbird eggs.

No tree squirrel was actually seen robbing a blackbird nest, but each time that Nests 52 and 58 lost eggs, shell fragments were found at the base of an adjacent tree in which a large, active Douglas squirrel had its nest, so the circumstantial evidence is nearly conclusive.² Originally, two eggs were taken from each nest, then, slightly less than two weeks later, the remaining eight nestlings disappeared.

Nest 69, on the other hand, was built high in a Jeffrey pine tree in which a Douglas squirrel also had a nest, yet the parent birds were able to successfully rear their seven charges. The squirrel's hole was twenty feet above the nest, which itself was 16 feet above the ground, in a well-hidden spot at the end of a comparatively low, but long limb which was leaved only at its extreme tip. Both birds and squirrel began building their nests at approximately the same time, and at no time did I ever see the latter out on the large, isolated limb bearing the birds' nest. Undoubtedly, the abundance of food was one of the contributing factors for the squirrel's ignoring of the nest, as well as the fact that the parent birds guarded the structure well, one always being in its vicinity.

Mephitis mephitis major, Great Basin skunk (0.53% biologic destruction, 0.65% predation, 2.08% secondary predation). While not uncommon in the region, I came across but one instance of a skunk noticing a blackbird nest, and, from his actions, curiosity was the predominating motivation.

Nest 6, built one and one-half feet from the ground in a small Wild peach, was exposed to almost any animal. While collecting bark beetles from a nearby Jeffrey pine tree, I looked up in time to see a large skunk with a minimum of white striping wandering in my direction. He failed to get my scent, and obviously did not see me, so I remained motionless. The Wild peach and its nest lay directly in his path, but he seemed to be unaware of it until the brooding bird flew up in his face. A few preliminary sniffs, and he decided to sample the contents. I made no movement, and know I did not disturb him; so, when he dropped the broken egg on the ground, licked its oozing contents without enthusiasm, sniffed at the nest a few times, and went on about his business, I decided he was not, at the moment, a hungry animal.

² Later, direct observations proved that this squirrel does eat blackbird eggs.

Crotalus viridis lutosus, Great Basin rattlesnake (2.68% biologic destruction, 3.29% predation, 10.41% secondary predation). Great Basin rattlesnakes were common in the vicinity, but only on one occasion did I notice any destruction of blackbird young. Coming home after dark one warm evening, I was plying the flashlight on the ground before me, for the location of a rattlesnake den nearby made some caution necessary. Passing Nest 90, the light centered on a medium-sized rattler lying across one side of a small sagebrush, the branches bending under his weight. The snake remained motionless over the nest for a moment, then, as I stood immobile, reached in and took the remaining nestling in his jaws, swallowing the tiny bird with no difficulty. Then he unobtrusively slid from the bush and made off leisurely.

3. *Incidental Predation.*—But one species could be assigned to this group: *Falco sparverius phalaena*, the Desert sparrow falcon (2.68% biologic destruction). The victim of this sparrow falcon was the female of Nest 32, and this is the only instance in more than ten years acquaintance with the species that I have ever seen an attack upon a blackbird.³ I saw the incident while watching the hawk crossing ahead of me while making one of my periodic surveys of the blackbird colony. Simultaneously, the female blackbird (the male was absent) swept up towards the low-flying falcon, to harry him on his way. I had seen such performances whenever the two came together, and was, in fact, looking for just such aggression while watching the falcon, for he was over heavily-nested territory, and was sure to be hazed by some indignant blackbird, vigilant in the defense of her nest. Speaking mildly, I was more than a little surprised when the falcon, instead of dodging and veering to shake off the blackbird, as he undoubtedly had been forced to do scores of times before, suddenly turned and grasped the bird. Together, they tumbled to the ground, breaking apart once on the way down, the falcon, as near as I could determine, immediately re-engaging his would-be assailant. Although the ensuing death struggle occurred within a few yards of me, I made no attempt to intervene, for the outcome of this unusual contest was of more importance to me than the satisfaction of saving one of many nesting blackbirds.

It did not last long. After quieting his victim, the falcon tugged industriously at the black feathers, looked up, saw me, and flew up, vanishing off over the chaparral in easy, graceful flight. The purpose of the falcon's attack is still a mystery to me. Perhaps he was hungry, and in search of a meal when the blackbird accosted him, as his tugging at the dead bird's feathers might indicate; or perhaps he had, more belligerently than others of his kind, killed in supposed self-defense.

The five nestlings from the dead bird's nest soon died of exposure, since I made no attempt to insinuate them into other nests, or care for them myself, having found from experience that neither is usually successful.

4. *Accidental Mortality.*—In this category are placed two instances of unintentional nest destruction by the following two species:

³ Except for an instance reported by the author in the *Condor* 1/43:66, 1941, but it was apparent, in this case that a Mormon cricket, upon which the blackbird was feeding, was the prey sought, and not the bird.

Erethizon epixanthum, the Western porcupine (3.67% biologic destruction, 63.63% accidental mortality). In this incident, Nest 75 was involved. For several days, a large porcupine had been seen in the vicinity of the north-west edge of the nesting colony. His activities on one tree greatly perturbed a large Douglas squirrel, who first drew my attention to the porcupine by his shrill scolding. One day, I found the bulky rodent climbing the small 15-foot tree in which Nest 75 was built. The nest itself was eight feet from the ground. The small tree, having a basal diameter of 10 inches, did not furnish too much gripping surface for the porcupine; consequently, his paws left few unexplored inches in his travels up and down the trunk. In so climbing, he tore down the nest and scattered the seven eggs on the ground, all of which were broken. I did not see the incident, but chanced by an hour or so later to find the porcupine gnawing the tender bark near the tree top. The nest fragments were still about the base of the tree, and the egg contents had not yet coagulated. A portion of the nest still clung to the original site.

Equus caballus, the Horse (2.14% biologic destruction, 36.36% accidental mortality). The remaining four eggs in Nest 26 were destroyed when the nest was knocked down by a small herd of horses. The small Mountain mahogany in which the nest was placed, jutted out into a seldom-used stock trail leading from a spring to the top of an adjacent ridge. The horses, wintered in another section, were driven to this vicinity each spring, and took up their old habits. In using their old trail, they each brushed against the small tree in passing, and in two days, had completely demolished the nest. A day before this happened, the harassed female bird was forced to leave the nest, which had become so dangerous she could no longer safely occupy it.

5. *Human Interference*.—The author's presence in the nesting colony was the direct cause of 6.98% of the total biologic destruction (13 eggs). Nest 11 affords a typical example.

I passed by this nest one morning on my way eastward, and found the six eggs in perfect condition. An hour later I returned, with no thought, at first, of looking in again; however, seeing the blackbird busily engaged about the inside, I stole up quietly to see what was going on. She was entirely oblivious to my approach, so absorbed was she with the business at hand and, in my anxiousness to see what held her attention, I stepped too close. With a squawk, she dove over the side of the nest, and flew several rods distant. Looking in, I found an egg freshly broken, undoubtedly damaged by the bird as she left. I left it in the nest, and found it there when I returned four days later.⁴ The female bird (I had never seen the male) flew up as I approached, but did not linger, flying off and disappearing in the chaparral. The eggs were only slightly warm, as if she had but lately returned to the nest after leaving long enough for them to cool. The next time I came by, the nest was empty, but otherwise disturbed, and the six eggs were cold. Thereafter, it disintegrated.

There was also evidence that the scent trails left from one nest to another

⁴ A division was inspected each day; thus it took four days to complete a survey of the entire four divisions. However, on many occasions, the 15-acre plot was worked in a single day, without any disruption in the usual schedule.

during my periodic inspections aided certain predators, principally weasels, in finding many of the nests. In fact, while no attempt was made to keep data on this particular problem, I feel that a large percent of those nests which were destroyed by unknown predators were found by this means.

In other instances, nervous nesting birds seemed sufficiently disturbed by my periodic presence to allow it to affect their brooding.

B. CLIMATIC FACTORS

Wind (0.87% total destruction, 1.28% total known destruction, 16.66% climatic destruction).—Nest 107 was found lying on the ground below the small pine tree in which it was built. One side was torn out, but the remainder was intact. The eggs lay nearby, and all had been broken by the fall. To all appearance, the short, high wind mentioned below in the account of Nest 88, blew it from its perch. Although more widespread damage had been expected among the blackbird nests after this wind, this was the only nest which I was able to find that had suffered appreciably.

Nest 88 was built out on the end of a slim, swaying pine branch, which every breeze swung to and fro. I was sitting uphill a few rods from this nest one clear day when the wind began to blow from the west, and soon was whipping across intervening clearings at a brisk rate. For a short time, I was anxious for the nestlings' safety as their structure swung wildly back and forth in various planes. Twice the branch's impetus so startled the bewildered brooding bird that she fluttered up from her perch, was flung several feet away by the wind, then laboriously regained her nest. She was the very picture of apprehensive alarm, but when I left she was still holding her own, and had accepted the situation for what it was. When next I passed, the fledglings were safe and sound.

Hail (4.37% total destruction, 6.86% total known destruction, 83.33% climatic destruction).—Nest 67 was typical. I was abroad in the vicinity of this nest when the rain turned to hail, and was watching the antics of the nesting birds. This female brooded longer than others watched who were in exposed situations, when the hail, small but powerful, began to pelt her strongly. The nest, already soggy, was rapidly becoming loose and unstable, but the bird stood it as long as possible. Finally she slipped over the side, and huddled for a short time beneath the bush, but soon flew off and disappeared in the storm. The hail rapidly tore down the abandoned nest, and the eggs dropped through the slender sagebrush branches, three falling to the ground, one lodging in the base of the bush.

C. MISCELLANEOUS

Of the remaining 89 eggs and nestlings, the three from Nest 89 were, for some unknown reason, scattered about on the ground below their nest when I came by one morning. None of them were yet ready to leave. They were placed back, but next day I found the nest again deserted, and was only able to find one nestling, who was dead. A solitary nestling from Nest 51 was apparently pushed out of the overcrowded nest by the other six, for I found

him beneath the nest on one of my rounds. I replaced him, but he was missing the following day.

Nest 8 unaccountably lost its mother during the third week of existence, and the two fledglings died of exposure. The remaining 83 eggs and nestlings disappeared without trace, and so were classed as unaccountables.

Protective Factors

1. *Floral Elements*.—Because of the variation in the amount of concealment afforded the nests, the flora played a major role in the safety of each nest. A general survey of the flora of the four divisions of the nesting plot showed the larger, denser plants prevailed in the areas of lowest general mortality, a positive indication that this was a protective factor. Of the four divisions, only the mortalities of the East and West can be evaluated as completely representative, for the Coyote Spring and Meadow Divisions were too small to be of real value in results obtained. Recourse to Table 1 will show that there is a definite correlation between the floral elements and the mortalities of the East and West Divisions, the Transition plants affording better protection to nests than the more open, lower Upper Sonoran elements.

2. *Nest Placement*.—This factor was significant, not only as regards the height of the structure above the ground, but also as the nest was well, or poorly concealed. Height would be expected to increase the safety factor for an individual nest, since it reduces materially the number of terrestrial predators to whom the nest is accessible. Although it might be supposed that tree frequenting bird predators would neutralize this advantage by concentrating on the high nests, the increased benefits accruing from height still maintain because of the rarity of these nests, only one out of nine being built in the Upper Level.

Concealment was, of course, of considerable significance, and low, well-hidden nests generally fared better than high, but exposed nests. However, useful concealment went hand-in-hand with the protective, or lack of protective, behavior of the parent birds. In most cases, it was observed that noisy, quarrelsome, conspicuous birds, such as those who persisted in pursuing other birds across the nesting areas, suffered more nesting mortality than quieter, more inconspicuous birds, because of the unnecessary attention they centered upon themselves. *Aphelocoma californica* and *Pica pica hudsonia*, in particular, seemed to benefit from this frequent exposure of position. On the other hand, there were instances where the mentioned predators avoided such quarrelsome blackbirds, and preyed upon the quieter birds they could find. Concealment also benefited nest owners during storms and high winds in giving better shielding.

3. *Defense of the Nest*.—The defense of the nest by the parent birds was of considerable importance. On one notable instance, I watched over 30 male blackbirds drive a large Redtail (*Buteo borealis calurus*) from the vicinity. Unlike the usual heckling behavior exhibited by one or two blackbirds when chasing a large hawk, the members of this pursuing flock evinced much more boldness, and several managed to strike the large raptore several times as he

TABLE 1.—Significance of Zonal Composition.

Division	% Mortalities by Nests		Zonal Composition	Zonal Protective Factors
	Levels (Total & Partial)	(Total & Partial)		
EAST (41 nests 202 eggs)	Upper	66.66	40% Transition — 60% Upper Sonoran	Mortality for the division is 87.80%. The dividing line between the Transition and Upper Sonoran in this division crosses the southwest corner. Transition elements lying SW of this line, Upper Sonoran, NE. Intrusives, of course, occupy both sides of the line. As would be expected, the predominance of the less concealing Upper Sonoran elements has resulted in a general higher mortality for this area than prevails in the following division. Comparison of the mortalities column will show that this is true irrespective of the heights of the nests above the ground.
	Middle	87.50		
	Lower	90.90		
WEST (49 nests 241 eggs)	Upper	50.00	100% Transition	Mortality for the division is 79.59%, substantially below that of the preceding area. This division lay well west of the dividing line between the two life zones, and from all apparent evidence, offered better concealment for nesting birds and their young. It will be noted that figures in the mortality column indicate not only this fact, but also that height of the nest above the ground was significant.
	Middle	78.57		
	Lower	83.87		
COYOTE SPRING (10 nests 48 eggs)	Upper	00.00	100% Transition	Mortality for the division is 60%. Results obtained from this and the following division are less reliable than those of the two divisions preceding because of the much smaller number of nests involved, but they do tend to corroborate conclusions drawn from the first two divisions; the author is inclined to believe that his presence in this division was the deciding factor in the higher mortality of this area over that shown by the following division.
	Middle	60.00		
	Lower	50.00		
MEADOW (7 nests 30 eggs)	Upper	50.00	100% Upper Sonoran	Mortality for the division is 57.14%.
	Lower	60.00		

dodged and twisted to escape them. On two other instances, solitary male blackbirds were noted characteristically worrying passing Redtails. On six separate occasions small bands of blackbirds drove solitary magpies from the vicinity, and the solitary crow who occasionally appeared was sure to be chased.

A significant example of nest protection was exhibited by a band of eight blackbirds who were harassing a magpie at the east, open edge of the colony. The magpie flew hastily off to the more wooded west, disappearing in a grove of pine trees with the blackbirds still in pursuit. Chancing to be walking in that direction, I followed them, but had no thought of seeing the magpie again that day. However, at the edge of the pine stand, I could plainly hear a commotion in the trees near the spot at which the birds had disappeared, and following the sounds, I came upon a strange sight. Half a dozen magpies and ten or twelve blackbirds were angrily circling a large pine tree, moving from perch to perch, and calling loudly, and occasionally one would dart in towards the tree with a raucous cry, then scamper out again. Sitting as close to the bole of the large tree as possible, was a large Western horned owl, his great, sleepy eyes following his tormentors, his beak snapping loudly as one would dart in and then dash away. The owl turned his head periodically to keep track of the birds on both sides of him, but what interested me was the manner in which blackbirds and magpies had forgotten their differences to heckle a common enemy which they both feared more than each other.

On another occasion, I watched the male of Nest 69 harry a large Redtail. Approaching the northwest edge of the blackbird colony late one morning, I heard a call of distress off to the north in thicker timber. Hurrying in the direction, I caught a fleeting glimpse of a cottontail (*Sylvilagus nuttalli grangeri*) scurrying off to the northwest. Simultaneously, a large Redtail rose from the ground and settled on a small Mountain mahogany and looked around. Immediately, the male blackbird, whose mate was brooding only a few yards away, flew into view and darted at the hawk. The latter swept heavily from the perch, and the blackbird flew in at every opportunity to peck at the hawk's feathers, the Redtail dodging each time as well as his bulk would permit. He flew a few rods northward, and again alighted, this time on top of a large, old lightning-struck pine stump nearly 50 feet tall. With this, the little pursuer returned to the vicinity of his nest.

Any hawk or other bird passing close to a blackbird nest was almost sure to be hurried on its way, while both male and female of Nest 26 on one occasion repeatedly flew threateningly into the face of the leading horse whose little band finally demolished their nest. The horse's only response was a slight snort and a shaking of the head.

Mortality for the division is 57.14%.

Upper Sonoran

50.00

Upper

MEADOW
(7 nests
30 eggs)

60.00

Lower

TABLE 2.

Nest No.	Distance in feet Above Ground	Built in	No. of Eggs	No. of eggs at End of 2 weeks	Causes of Absence	% Mortality	No. of Nestlings Matured	Causes of Absence	% Mortality	No. of Sterile Eggs at End of 4 Weeks
1.	8	<i>Pinus ponderosa jeffreyi</i>	6	6		0	6		0	0
2.	2	<i>Prunus andersoni</i>	6	6	<i>Pituophis c. deserticola</i>	0	5	Unknown	16-2/3	16-2/3
3.	4	<i>Amelanchier alnifolia</i>	4	3	(<i>Citellus g. beecheyi</i>)	25	0	Unknown	100	100
4.	3.5	<i>Artemisia tridentata</i>	7	0	(<i>Aphelocoma californica</i>)	100	33-1/3		100	33-1/3
5.	5.5	<i>Amelanchier alnifolia</i>	6	4	<i>Mephitis m. major</i>	20	4	(<i>Coluber taeniatus</i>)	100	100
6.	1.5	<i>Prunus andersoni</i>	5	4	Unknown	100	0		100	100
7.	11	<i>Cercocarpus ledifolius</i>	4	0	Unknown	33-1/3	0	Parents' disappearance	100	100
8.	7	<i>Prunus demissa</i>	3	2	Unknown	16-2/3	5	<i>Aphelocoma californica</i>	16-2/3	16-2/3
9.	6	<i>Pinus p. jeffreyi</i>	6	3	Unknown	33-1/3	0		100	100
10.	10	<i>Purshia tridentata</i>	3	2	Human interference	100	0		100	100
11.	3.5	<i>Artemisia tridentata</i>	6	0	Unknown	100	0		100	100
12.	3.5	<i>Artemisia tridentata</i>	3	0	Unknown	0	5		0	0
13.	12	<i>Libocedrus decurrens</i>	5	5	<i>Citellus g. beecheyi</i>	33-1/3	4		33-1/3	33-1/3
14.	4	<i>Cercocarpus ledifolius</i>	6	4	Unknown	0	3	(colubrid)	0	0
15.	6	<i>Amelanchier alnifolia</i>	3	3	Unknown	33-1/3	0		100	100
16.	1	<i>Amelanchier alnifolia</i>	3	2	Unknown	20	4	(<i>Coluber taeniatus</i>)	20	20
17.	3.5	<i>Artemisia tridentata</i>	5	4	(<i>Coluber taeniatus</i>)	33-1/3	0		100	100
18.	3.5	<i>Purshia tridentata</i>	6	4	<i>Pica pica hudsonia</i>	100	0		100	100
19.	7	<i>Pinus p. jeffreyi</i>	6	0		0	4		0	0
20.	3	<i>Prunus andersoni</i>	4	4	Unknown	14.28	0	<i>Accipiter velox</i>	100	100
21.	10	<i>Cercocarpus ledifolius</i>	5	5	Hailstorm	100	0	(<i>Pica</i> or <i>Aphelocoma</i>)	100	100
22.	6.5	<i>Prunus demissa</i>	7	6	Unknown	33-1/3	2		33-1/3	33-1/3
23.	6	<i>Prunus demissa</i>	3	0	<i>Aphelocoma californica</i>	100	0	<i>Equus caballus</i>	100	100
24.	5	<i>Prunus demissa</i>	3	2	Unknown	33-1/3	0	One egg sterile	25	1
25.	2	<i>Artemisia tridentata</i>	6	0	Unknown	0	6		0	0
26.	5	<i>Cercocarpus ledifolius</i>	6	6	Unknown	25	0	Unknown	100	100
27.	4	<i>Artemisia tridentata</i>	6	4	(<i>Aphelocoma californica</i>)	14.28	6	Unknown	100	100
28.	3	<i>Artemisia tridentata</i>	6	6	Unknown	33-1/3	0	Unknown	100	100
29.	6	<i>Pinus p. jeffreyi</i>	6	3	Unknown	100	0	<i>Corvus b. hesperia</i>	100	100
30.	11	<i>Cercocarpus ledifolius</i>	7	6	(<i>Aphelocoma californica</i>)	25	0		0	0
31.	4	<i>Amelanchier alnifolia</i>	7	6	Unknown	33-1/3	0		100	100
32.	1.5	<i>Prunus andersoni</i>	3	2	<i>Falco s. phalaena</i>	100	0		100	100
33.	5	<i>Artemisia tridentata</i>	4	3	Unknown	25	0		40	1
34.	3.75	<i>Purshia tridentata</i>	5	4	(<i>Mustela f. nevadensis</i>)	20	3	One egg sterile (Human interference)	40	1

Artemisia tridentata	3	4	4	0	3	One egg sterile	25
Artemisia tridentata	28.	6	6	0	6	Unknown	0
Pinus p. jeffreyi	30.	4	3	25	0	Unknown	100
Cercocarpus ledifolius	31.	7	6	14.28	6	Unknown	14.28
Amelanchier alnifolia	32.	3	2	33-1/3	0	Unknown	100
Prunus andersoni	33.	5	0	100	0	Unknown	100
Artemisia tridentata	34.	4	3	25	0	Corvus b. hesperis	100
Purshia tridentata	3.75	5	4	(Mutsaers f. nevadensis)	20	One egg sterile	40
Pinus p. jeffreyi	8	7	6	Human interference	14.28	(Human interference)	100
Artemisia tridentata	35.	3	6	Unknown	0	One egg sterile	33-1/3
Artemisia tridentata	36.	2	0	Unknown	16-2/3	(Pica p. hudsonia)	100
Amelanchier alnifolia	37.	6	5	Unknown	100	One egg sterile	100
Artemisia tridentata	38.	4.25	0	Pitheophis c. deserticola	16-2/3	One egg sterile	33-1/3
Artemisia tridentata	39.	5.5	4	Hailstorm	100	Three eggs sterile	100
Artemisia tridentata	40.	2.25	6	Unknown	16-2/3	Three eggs sterile	83-1/3
Artemisia tridentata	41.	4	5	Unknown	66-2/3	Unknown	0
Purshia tridentata	42.	6	6	Unknown	0	Unknown	100
Pinus p. jeffreyi	43.	6	2	Unknown	66-2/3	Unknown	0
Pinus p. jeffreyi	44.	5	3	Unknown	0	(Pica p. hudsonia)	0
Prunus andersoni	45.	3	3	Unknown	40	One egg sterile	100
Artemisia tridentata	46.	3	4	Unknown	0	One egg sterile	25
Artemisia tridentata	47.	4	4	Unknown	57.14	Unknown	0
Artemisia tridentata	48.	6.5	3	Unknown	0	Unknown	100
Pinus p. jeffreyi	49.	7	3	Unknown	0	Two eggs sterile	40
Pinus p. jeffreyi	50.	4	5	Unknown	33-1/3	Left prematurely	14.28
Cercocarpus ledifolius	51.	4.5	7	(Scurius douglasi)	100	Scurius douglasi	100
Cercocarpus ledifolius	52.	5	6	Corvus b. hesperis	50	Unknown	50
Cercocarpus ledifolius	53.	3.75	5	(Pica p. hudsonia)	50	Unknown	100
Purshia tridentata	54.	4	2	Unknown	60	Two eggs sterile	100
Artemisia tridentata	55.	3.5	6	Unknown	100	Two eggs sterile	100
Cercocarpus ledifolius	56.	4.75	5	Hailstorm	33-1/3	(Scurius douglasi)	100
Cercocarpus ledifolius	57.	5.5	4	Successful maturation	0	Unknown	0
Amelanchier alnifolia	58.	4.25	6	Unknown	0	Unknown	0
Pinus p. jeffreyi	59.	13	3	Unknown	0	Unknown	0
Pinus p. jeffreyi	60.	4	7	Unknown	0	Unknown	0
Amelanchier alnifolia	61.	3	7	Unknown	0	Unknown	0
Artemisia tridentata	62.	5	5	Aphelocoma californica	60	Unknown	60
Artemisia tridentata	63.	2.5	2	(-Basariscus a. raptor)	100	Unknown	100
Cercocarpus ledifolius	64.	6	0	Callospermophilus chrysodeirus	100	One egg sterile	100
Pinus p. jeffreyi	65.	7.5	3	Unknown	14.28	Unknown	20
Artemisia tridentata	66.	4.25	5	Unknown	100	Unknown	14.28
Artemisia tridentata	67.	2.5	7	Hailstorm	100	Unknown	100
Artemisia tridentata	68.	3	4	Unknown	33-1/3	Unknown	33-1/3
Pinus p. jeffreyi	69.	1	6	Unknown	0	Unknown	0
Prunus andersoni	70.	16	7	Unknown	0	Unknown	0
Pinus p. jeffreyi	71.	6	4	Callospermophilus chrysodeirus	50	Unknown	50
Cercocarpus ledifolius	72.	3	4	Unknown	100	Unknown	100
Pinus p. jeffreyi	73.	12.5	3	Unknown	100	Unknown	100
Cercocarpus ledifolius	74.	6	3	Unknown	100	Unknown	100
Pinus p. jeffreyi	75.	7.5	3	(Aphelocoma californica)	100	Unknown	100

TABLE 2—(Continued)

Nest No.	Distance in feet Above Ground	Built in	No. of Eggs	No. of eggs at End of 2 weeks	Causes of Absence	% Mortality	No. of Nestlings Matured	Causes of Absence	% Mortality	No. of Sterile Eggs at End of 4 Weeks
75.	8	<i>Pinus p. jeffreyi</i>	5	0	<i>Erethizon epixanthum</i>	100	4	One egg sterile	20	1
76.	3.5	<i>Artemisia tridentata</i>	6	6		0	6		0	
77.	2	<i>Ribes nevadense</i>	6	6		0	6		0	
78.	3.5	<i>Parshia tridentata</i>	3	3		0	0	(<i>Citellus g. beecheyi</i>)	50	
79.	0.5	<i>Prunus andersoni</i>	3	3		0	0	Unknown	100	
80.	2	<i>Artemisia tridentata</i>	4	2	(<i>Pituophis c. deserticola</i>)	50	1	One egg sterile	75	1
81.	6	<i>Pinus p. jeffreyi</i>	6	0	<i>Basariscus a. raptor</i>	100			100	
82.	6	<i>Cercocarpus ledifolius</i>	6	0	Unknown	100			100	
83.	2.5	<i>Artemisia tridentata</i>	4	0	<i>Pica p. hudsonia</i>	100	2	Two eggs sterile	100	2
84.	1.5	<i>Artemisia tridentata</i>	4	4		0	0	<i>Bubo v. pallascens</i>	50	
85.	9	<i>Pinus p. jeffreyi</i>	4	4		0	0	<i>Coluber c. mormon</i>	66-2/3	1
86.	4	<i>Cercocarpus ledifolius</i>	6	6	Unknown	100	2		100	
87.	4.25	<i>Aemelanchier alnifolia</i>	3	0		0	4	One egg sterile	20	1
88.	6.5	<i>Pinus p. jeffreyi</i>	5	5		0	0	Left prematurely	100	
89.	3	<i>Artemisia tridentata</i>	3	3	<i>Crotalus v. lutosus</i>	100	0		100	
90.	1	<i>Artemisia tridentata</i>	5	0						
COYOTE SPRING DIVISION										
91.	6	<i>Alnus tenuifolia</i>	7	5	(<i>Aphelocoma californica</i>)	28.57	0	<i>Pica p. hudsonia</i>	100	
92.	12.5	<i>Pinus p. jeffreyi</i>	3	3		0	3		0	
93.	3	<i>Artemisia tridentata</i>	3	3		0	3		0	
94.	4.5	<i>Cercocarpus ledifolius</i>	3	3		0	3		0	
95.	2	<i>Artemisia tridentata</i>	5	0	<i>Citellus mollis</i>	100			100	
96.	5	<i>Artemisia tridentata</i>	4	0	(<i>Mustela f. nevadensis</i>)	100	6		0	
97.	6.5	<i>Cercocarpus ledifolius</i>	6	6		0			100	
98.	7	<i>Libocedrus decurrens</i>	7	0	<i>Mustela f. nevadensis</i>	100			100	
99.	4	<i>Abies concolor</i>	4	0	<i>Cyanocitta s. frontalis</i>	100	6		100	
100.	8	<i>Libocedrus decurrens</i>	6	6		0			0	
MEADOW DIVISION										
101.	3	<i>Prunus demissa</i>	6	6		0	5	One egg sterile	16-2/3	1
102.	2	<i>Artemisia tridentata</i>	3	2	<i>Pituophis c. deserticola</i>	33-1/3	3	Unknown	33-1/3	
103.	1.5	<i>Prunus andersoni</i>	5	5		0	3	Unknown	40	
104.	3.5	<i>Artemisia tridentata</i>	4	4		0	2		50	1
105.	4	<i>Artemisia tridentata</i>	4	4		0	4		0	
106.	20	<i>Pinus p. jeffreyi</i>	5	5		0	0	One egg sterile	20	1
107.	11	<i>Pinus p. jeffreyi</i>	3	3		0	0	Wind destroyed nest	100	
			521	327		37.23	205		60.65	23

Av. nest ht. = 5.07 ft.

In this study, it was found that height of the nest above the ground, the amount of natural concealment afforded by the plant chosen as the nesting site, and the protective behavior of the parent birds were definite operative forces in reducing or raising the mortality of nesting birds and their eggs.

A total of 107 pairs of nesting blackbirds produced 521 eggs, 205 of which matured to leave the nest safely, a mortality of 60.65%. From observations continued after the period covered in this report, the author is inclined to believe that the mortality among these matured nestlings probably reaches 50% or more within the month following their leaving the nest. This would reduce the number of successfully-matured birds to an average of one per nesting pair of adult birds, which is probably an approximate estimate of the true picture, since four years observance of the area studied showed that the number of nesting adults who returned each season did not seem to vary perceptibly. A one-third increase in the size of the band each nesting season would probably be adequate to keep its numbers fairly constant, and allow for continual loss from predation, etc.

Sagebrush (*Artemisia tridentata*), the most prevalent shrub, was most often used as a nesting site, even in the entirely Transition West Division. Other plants which served as nesting sites, in the order in which they were most used, were *Pinus ponderosa jeffreyi*, *Cercocarpus ledifolius*, *Prunus demissa*, *Prunus andersoni*, *Amelanchier alnifolia*, and *Purshia tridentata*. *Librocedrus decurrens*, *Abies concolor*, and *Ribes nevadense* completed the floral array.

ZOOLOGICAL LABORATORIES,
UNIVERSITY OF NEVADA,
RENO, NEVADA

Introduction to the Study of the Reptiles of Indiana¹

Sherman Minton, Jr.

The reptile group has become an increasingly popular one for students of natural history, and I have accordingly thought it desirable to incorporate my own observations, made over a period of several years, in a general account of the reptiles of the state. It is hoped that the descriptions and observations assembled from the literature may be useful to amateur naturalists and in the schools. The last comprehensive account of the reptiles of Indiana is in *The Batrachians and Reptiles of the State of Indiana* by O. P. Hay, published in 1892.

Turtles—Order Testudinata

Turtles are probably better known to the average person than are reptiles of other sorts. Fourteen species belonging to four different families inhabit Indiana. The majority of these are common and widely distributed. Most of them are semiaquatic and hence are seen in greatest numbers in the neighborhood of ponds, lakes, and streams. None of these turtles are dangerous to human life; however, the bites of the larger species may be painful or even mutilating. Turtle meat is esteemed as an article of diet in some localities, and the eggs are sometimes eaten. About a half-dozen species are used for food to a greater or lesser degree.

The Mud Turtles—Family Kinosternidae

The turtles of this group are rather small, inconspicuous creatures of strictly aquatic habitat. They are relatively weak swimmers but are adapted to life on the bottom.

COMMON MUSK TURTLE—*Sternotherus odoratus* (Latreille).

Description.—Carapace highly arched and not flared at the margins; smooth in adults but showing three keels in young specimens. Color dirty brown to black. Plastron composed of five paired shields and divided into two movable lobes with a fixed central portion. Pectoral shields quadrangular in shape. Head proportionately large, (larger in the male than in the female), blackish in color, with two longitudinal yellow stripes on each side.

Size.—Average length of carapace 4 inches; width 3 inches. Weight 4 to 7 ounces. The young are about an inch long and nearly as wide.

¹ Lieutenant Minton's manuscript was not entirely completed for publication at the time of his departure for the Army, and has been edited by Mr. Karl P. Schmidt who has supplied an introductory paragraph and a brief bibliography. The references given are to general works only, and include two books on amphibians which would be useful to school libraries. These works contain further references to papers on the amphibians and reptiles of Indiana. Many short papers on Indiana reptiles will be found in the Proceedings of the Indiana Academy of Science and in the American Midland Naturalist.

Distribution.—Common throughout the state.

Habits.—These turtles prowl along the bottoms of muddy streams and ponds and remain submerged for long periods. They rarely venture out of the water even to sun themselves; although the young may be found lying in very shallow places during the early spring. The adults are often taken in fish traps.

Musk turtles feed indiscriminately upon mollusks, worms, aquatic insects, fish, and carrion. They probably perform a useful service as scavengers, but are little loved by fishermen because of their talent for stripping the bait from a hook.

Females leave the water during the early summer to lay their eggs which are roughly spherical with hard, brittle shells. The eggs may be buried in sand or loose soil, hidden under a log or mass of debris, or occasionally left in the open.

Newly-captured musk turtles are usually bad-tempered, trying to bite everything within reach and giving off the unpleasant odor from which the species takes its name. They usually become tame in a short time and do well in captivity.

COMMON MUD TURTLE—*Kinosternon subrubrum subrubrum* (Lacépède).

Description.—Carapace smooth, moderately arched, not flared at the margins, and dull brown in color. Plastron similar to the preceding species except that the pectoral shields are triangular in shape. Head dark brown spotted with yellow on the sides.

Size.—Length of carapace $3\frac{1}{2}$ inches; width $2\frac{1}{2}$ inches.

Distribution.—Reported by Grant from Jasper-Pulaski State Forest and the southwestern part of Starke County. Reported by Hay from near Bloomington and collected by Blatchley near Terre Haute. I saw a shell of this species in a curio shop in Martinsville but was unable to ascertain its source.

Habits.—Very similar to the musk turtle save that it is less aquatic and of a more tractable disposition. Ponds and ditches seem to be preferred to running streams. Females are said to lay their eggs at a considerable distance from the water.

The Snapping Turtles—Family Chelydridae

To this family belong some of the largest fresh-water turtles in the world. As their name implies, they are belligerent creatures with powerful jaws. They have large heads, long tails, and relatively small under shells.

One species is common in Indiana. The giant alligator turtle of the South has in times past been taken along the lower Ohio and Wabash Rivers; however, it must now be considered as a rare wanderer rather than a native of the state.

SNAPPING TURTLE—*Chelydra serpentina serpentina* (Linnaeus).

Description.—Carapace flat, serrated behind, smooth in adults but very rough with three keels in the young, color blackish to a pale dull brown or gray. Plastron small and rhomboid. Head large; limbs stout and powerful; tail

nearly as long as the carapace and bearing a prominent ridge of horny plates.

Size.—The average Indiana adult has a carapace about 11 inches long and of approximately equal width in the widest portion. Such a turtle would weigh 10-12 pounds. Very large specimens may show a carapace 16-18 inches in length and weigh in the neighborhood of 30 pounds.

Distribution.—Common over the entire state.

Habits.—This is the largest of Indiana turtles and the only one capable of doing much bodily harm to human beings. Once removed from the security of its aquatic environment, the snapper is a bold, tough antagonist. Raising its body on its stubby legs, the turtle lunges rapidly with open jaws which, in the case of a large individual, are strong enough to amputate a finger or sever the tendons of a hand or foot. The long, stout tail, however, provides a means of catching and holding even the largest specimen.

Almost any body of water from the largest rivers and lakes to such inconsequential streams as the Indiana University "Jordan River" may harbor the snapping turtle. As a rule, it likes warm, sluggish water with much aquatic vegetation. The shells of many individuals become heavily grown with algae. These turtles are not often seen basking but lie in shallow water with the tips of their noses protruding. Occasionally they are seen crossing some road or field far from the water. Sometimes these wanderers are females seeking a nesting site; more often, they seem to be following some poorly understood migratory urge.

Snapping turtles catch and eat all sorts of aquatic and semiaquatic animals, both vertebrate and invertebrate. Considerable carrion is eaten, as well as some vegetable food; I saw a very large individual browsing upon floating petals of the tulip tree. These turtles destroy some young ducks and other water fowl as well as some food and game fish; they are useful as scavengers, and as feeding upon noxious invertebrates.

The eggs of the snapping turtle are spherical, hard-shelled, and 10 to 30 in number. They are laid during June and are buried by the female in warm, moist soil often at some distance from the water.

Snapping turtle meat, fried or in soup, is eaten in many towns along the Ohio River. It is somewhat stringy but the flavor is good.

Although sullen and ungainly, this species is one of the hardiest of captives. It has been my experience that it lives in harmony with turtles of smaller species.

The Pond and Box Turtles—Family Testudinidae

This group combines several genera of the smaller fresh-water turtle, including several of the commonest Indiana species, and also the box-turtles, which are almost entirely land animals.

COMMON MAP TURTLE—*Graptemys geographica* (LeSueur).

Description.—Carapace moderately flat, flared at the margins, and slightly serrated behind. Color dark green to olive-brown with a net-work of greenish-yellow lines. A fairly prominent keel runs down the center of the carapace.

The plastron is large, immobile, and yellow in color. The head is chunky with a small triangular spot behind the eye. The head, legs, and tail are dark green with narrow yellow stripes.

Size.—Length of carapace 8 inches; width $6\frac{1}{4}$ inches; weight 3 pounds. The males of this species are appreciably smaller and have proportionately longer tails and smaller heads than the females.

Distribution.—The entire state, more common in the northern half.

Habits.—Inhabits lakes and the larger streams of the state. Individuals of all sizes may be seen literally piled upon projecting rocks and floating logs. At the least alarm, the entire group flounders off into the water.

This turtle appears to feed almost exclusively upon snails and other mollusks; although small amounts of carrion, fish, and insects may be eaten.

The eggs of the map turtle number about a dozen and are laid in loose soil usually quite close to the water.

Evermann and Clark report that these turtles were active during the winter at Lake Maxinkuckee and could even be seen swimming under the ice. We have seen them active well through November on mild days.

The young of this species are often taken as aquarium pets, but they usually do not live long. Similarly, the adults are delicate in captivity. They are very shy and gentle. This is regarded as an edible species, but it does not seem to be eaten in Indiana.

MISSISSIPPI MAP TURTLE—*Gratemys pseudogeographica pseudogeographica* (Gray).

Description.—General shape similar to the preceding species. The carapace is more prominently keeled and deeply serrated on the hind edge. There is a dark spot on most of the shields, and the reticulated pattern is less evident. The head and legs are striped and there is a prominent hook or crescent-shaped yellow mark behind the eye.

Size.—About the same as *G. geographica*.

Distribution.—More or less supplanted *G. geographica* in the southern third of the state.

Habits.—The larger, sluggish streams as well as ponds and bayous are the haunts of this turtle. It is thoroughly aquatic, shy, and difficult to capture. Most of our specimens were taken by fishermen from their lines.

According to Pope, the young of this species feed upon mollusks and insects while the adults feed primarily upon aquatic vegetation. My captive specimens showed no such discrimination.

This turtle seems to be hardier in captivity than the common map turtle. The Mississippi map turtle is an edible species and is occasionally taken for food in southern Indiana.

CENTRAL PAINTED TURTLE—*Chrysemys picta marginata* Agassiz.

Description.—Carapace moderately flat, slightly flared at the margins, and not serrated or keeled. Color greenish-black to chocolate brown with crescentic

red markings on the marginal plates. The plastron is large, not hinged, and usually creamy-yellow in color with a large dark mark in the center. In some specimens, the entire plastron is rusty-red with a dark center. The head is rather small, dark on top with a yellow line from the eye to the angle of the jaw. The chin and throat are olive striped with yellow. The legs and tail are dark with red stripes.

Size.—Length of carapace $5\frac{1}{2}$ inches; width $4\frac{3}{4}$ inches. Females are appreciably larger than males. The males have very long claws on their forelimbs.

Distribution.—Common over the entire state.

Habits.—Found everywhere in warm, shallow bodies of water, this is probably the commonest Indiana turtle. It is usually seen sun-basking or leisurely swimming on the surface. If frightened, it dives and conceals itself in the mud or vegetation. It is sometimes found at a considerable distance from the water. In my experience, these individuals are usually females seeking nesting sites.

Studies made by Surface and others on the feeding habits of the painted turtle show that about equal amounts of animal and plant matter are consumed. The animal food consists chiefly of insects, mollusks, and vertebrates, the latter mostly as carrion. My captives ate chiefly animal food and showed considerable agility and aggressiveness in catching small fish and frogs. They showed little interest in plant food.

Several eggs of this species as well as a great many fragments of eggshells were dug from a clay bank about fifty feet from a pond near Jeffersonville. It appeared that several females had been using the bank as a nesting place. The eggs were ovoid and about an inch in length with thin, tough, flexible shells.

Activity of these turtles on mild days during the winter has repeatedly been observed in southern Indiana. At such times, they are usually seen swimming and may be readily captured.

As a captive, this is an attractive, gentle, hardy species. It should be provided with enough water to allow it to submerge its head but should not be kept in deep water unless given some object on which to rest.

HIEROGLYPHIC TURTLE—*Pseudemys concinna hieroglyphica* (Holbrook).

Description.—Carapace low, flattened, and flared at the margin. Color dark brown with labyrinthine designs on each shield. Plastron yellowish with a dark branching pattern. Head dark with light lines on the neck and chin and light crescentic marks on top of the head. Legs and tail striped.

Size.—Average length of carapace 12 inches; width 8 inches; weight 8 pounds.

Distribution.—Rare in southwestern Indiana. I have a fairly reliable sight record for a swamp in southern Knox County.

Habits.—Like most of the related species, it spends most of its time floating and sun-bathing. Its food consists of small fish, insects, crayfish, and carrion. It frequents fairly large bodies of water and rarely goes ashore.

CUMBERLAND TURTLE—*Pseudemys scripta troosti* (Holbrook).

Description.—Carapace rather flat and depressed. Adult carapace smooth; young with a prominent keel. Color grayish-green with many narrow yellow marks. Plastron yellow with large black spots. Head greenish with an oval bright red spot behind the eye and a yellow stripe from the eye to the chin. Throat, legs, and tail greenish striped with yellow.

A melanistic form occurs in which both the carapace and soft parts are very dark and the prominent head markings obscure; it has been shown that this color phase is confined to adult males.

Size.—Average length of carapace 8 inches; width $6\frac{1}{4}$ inches.

Distribution.—Fairly common in southwestern Indiana; apparently rare in the southeastern counties. I have collected the melanistic form in Owen County.

Habits.—Very similar to the other pond turtles in general behavior. It seems to frequent the larger bodies of water. It is largely carnivorous in its feeding taking all sorts of small animals living and dead.

Eggs are laid in open, sandy places near the water. Like some other turtles, the female uses water from her bladder and cloaca to soften the ground before digging her nest.

The young of this species comprise the majority of the "Ten-Cent Store Turtles" offered for sale. Given an aquarium with some means of leaving the water and a diet of chopped meat, earthworms, and lettuce leaves, it is a hardy captive. As a rule, it is a docile reptile; but a big one caught on a fish line at Hovey Lake defended itself as vigorously as a snapping turtle.

SPOTTED TURTLE—*Clemmys guttata* (Schneider).

Description.—Carapace moderately arched and slightly flared at the edges. Color black with small, round yellow or orange spots. Plastron yellow, orange, or pinkish with large black blotches. Head black with a large yellow spot on the temporal region and smaller scattered spots. Legs and tail blackish above and dark orange or pink below.

Size.—A small turtle with an average shell length of 4 inches and width of slightly less than 3 inches.

Distribution.—Occurs locally in northern Indiana. Indianapolis seems to be the southernmost extent of its range.

Habits.—An inhabitant of marshes and shallow ponds, this turtle is less aquatic than the other members of the group. Although often seen swimming or sun-basking in company with the other pond turtles, the spotted turtle often leaves the water to wander into dried-up swamps and damp meadows. As turtles go, it is astonishingly quick on land.

Spotted turtles feed principally upon insects and small frogs. Crustaceans and small amounts of carrion and vegetable matter are also eaten. At least part of this food is found and eaten on land.

Usually two or three eggs are laid in a hole dug by the female. The young have a nearly circular shell and very few spots.

Small size, attractive colors, and a gentle disposition make this species a desirable pet. It becomes quite tame and may live for years.

BLANDINGS TURTLE—*Emys blandingii* (Holbrook).

Description.—Carapace arched, very slightly flared at the edges, and lacking a keel in the adult. Color black, heavily sprinkled with pale yellow dots. Plastron dark yellow, hinged in the middle, and notched at the hind end. Head dark with small yellow spots, lower jaw and throat bright yellow, legs and tail blackish.

Size.—Carapace length $7\frac{1}{2}$ inches; width $5\frac{1}{2}$ inches; weight about 3 pounds.

Distribution.—The northern fourth of the state. It does not appear to be very common.

Habits.—In choice of habitat, this reptile is intermediate between the primarily aquatic pond turtles and the terrestrial species of *Terrapene*. We have collected but two specimens. One was found on the bottom of a shallow stream, the other in a small weed-choked ditch. Although there are numerous instances of its being found on land, it probably does not wander far from marshes or sluggish streams.

The food of Blanding's turtle consists of frogs, tadpoles, minnows, and various invertebrates as well as fruits, berries, and tender shoots. A good part of its food is obtained on land.

The eggs are laid in a hole scooped out by the female with her hind feet. The eggs number about a half dozen and require some two months to hatch.

Pope states that no turtle of this species has lived over three years in captivity. We kept a specimen about two months before releasing it. It took food readily and seemed to thrive under artificial conditions.

COMMON BOX TURTLE—*Terrapene carolina* (Linnaeus).

Description.—Carapace highly arched with a low, mid-line keel and slightly flared margin. The pattern is highly variable but generally consists of radiating yellow or orange spots and stripes on a black or dark brown background. The plastron is yellow suffused with black or brown or may sometimes be uniformly black. The head is rather small with a hooked beak. In old males, the skin of the head and neck is bright yellow or orange with prominent spots. Females and young males have brown heads with or without yellow spotting. The eye in the male is bright red; that of the female dark red or brownish. The power of closing the plastron by a hinge at its middle gives the name "box turtle" to the genus *Terrapene*.

Size.—Length of carapace $5\frac{1}{2}$ inches; width $4\frac{1}{4}$ inches. Contrary to general rule, the males seem to be slightly larger than the females.

Distribution.—The entire state but more common in the southern half.

Habits.—Shaded woodland especially in hilly areas is preferred by this interesting turtle. It is seclusive in habits and is rarely seen abroad save on warm, rainy days or during the spring and fall. Box turtles are intolerant of excessive heat and, during the summer, seek the coolness of shallow streams, ponds, and bogs. In such spots, they congregate in large numbers and soak in the water or bury themselves in the mud. I once counted 32 turtles in a distance of about half a mile along a small creek and, on another occasion,

removed 14 adult individuals from a mud hole about the diameter of a wash tub. This summer search for water causes many of these turtles to fall into wells and reservoirs where they become exhausted and drown.

Box turtles are the most omnivorous of reptiles. Their food includes many fruits and vegetables, mushrooms and other fungi, insects, worms, slugs, snails, and carrion. These turtles sometimes appear in strawberry, tomato, or melon patches in numbers sufficient to do appreciable damage. On the other hand, they destroy various harmful insects and act as scavengers.

On about October 20, a very fat female box turtle was seen preparing to hibernate under a rose bush where the soil was fairly soft and covered with leaves. She dug very slowly and seemed to be sinking vertically into the ground. She was not seen to leave her burrow once it was begun. Until about November 10, she protruded her head occasionally; and her carapace was barely underground on November 29. She was not seen again until April 14. Examination of her burrow showed that she was probably never more than five inches below the surface.

I have seen female box turtles digging their nests on June 15, June 26, and July 1. Each time the day was damp and overcast and the ground wet. The site selected was a flat, well-drained clearing in every case but one in which the turtle was digging in an abandoned road in thick forest. The digging was done with alternate rotary motions of the hind feet. I did not actually see the eggs laid in any instance. On July 23, three eggs were brought to me by a farmer who had dug them up and mistaken them for snake eggs. The eggs were oval, about an inch in length with a thin, tough shell. Two of them hatched on August 29.

During 1933-34, I collected about 75 of these turtles and released them, suitably marked, in my neighborhood at New Albany. About half of them wandered away or were killed by automobiles. The remainder settled down in a relatively restricted space, and some stayed in the vicinity for years, one or two even surviving the 1937 flood. They showed a tendency to return to certain favorite places year after year.

Box turtles are surprisingly tough and hardy creatures. One of my marked specimens had its shell badly cracked by a glancing blow from an automobile tire but survived this injury and was found alive and well a year later. Another specimen lost approximately half of its carapace in some sort of mishap. The defect was healed by a thick, leathery skin in which some pieces of the original shell were imbedded. An occasional specimen is found with a bare, bone-white carapace apparently the result of having been burned in a brush fire.

ORNATE BOX TURTLE—*Terrapene ornata* (Agassiz).

Description.—Carapace highly arched, flattened on top, and without a keel. Color reddish-brown to chocolate with radiating stripes and spots of bright yellow. Plastron dark with many yellow lines of different lengths.

Size.—Smaller than the common box turtle. Carapace about 4 inches long and $3\frac{1}{2}$ inches wide. Grant describes Indiana specimens as "runts" compared with those from the Western States.

Distribution.—This is a western species which has extended its range into northwestern Indiana within comparatively recent times. It is recorded by Grant from Starke and Jasper Counties and is found eastward to Marshall County.

Habits.—Found in open, sandy prairie in contrast to the forest-loving common box turtle. It apparently does not have the latter's aquatic tendencies but relies upon shallow burrows to protect it from the heat.

According to studies of the stomach contents of wild specimens, this turtle eats insects and other animal food to a greater extent than does the common box turtle; however this may chiefly be due to difference in habitat.

The Soft-Shell Turtles—Family Trionychidae

The two Indiana species of this family are unique and may be instantly distinguished from all other turtles. They are extremely flat; and in place of the horny shell of other turtles, they are covered by a tough, flexible, leathery integument. Their necks are long and snaky, and their heads terminate in long, tapering, soft snouts. Their feet are broad and heavily webbed.

SPINY SOFT-SHELLED TURTLE—*Trionyx spiniferus* (LeSueur).

Description.—This species is recognizable at close range by the row of small spines or tubercles along the anterior border of the carapace and by the crescent-shaped nostrils. The partition between the nostrils bears a flange on each side.

The carapace is olive margined with yellow and narrowly bordered with black. Scattered over the dorsal surface are numerous circular black markings. The plastron is uniformly white, and the head, legs, and tail are olive-brown with light stripes. Old specimens gradually lose their markings and become a uniform muddy brown.

Size.—Not infrequently reaches a carapace length of 13 inches and a weight of 7 to 10 pounds; however a length of 10 inches and width of 8 inches is probably more nearly average.

Distribution.—The entire state.

Habits.—Few reptiles are so well-adapted to an aquatic life as is this turtle and its related species. They have even developed a form of under-water respiration in which oxygen is removed from the water as it is forced through the vascular pharynx. Their strong webbed feet and flat shape make them agile swimmers, while the long proboscis allows them to breathe air while almost totally submerged.

The larger lakes and large, deep streams with a mud or sand bottom are preferred by the soft-shelled turtles; however, I saw several large ones in a small drainage ditch near the Kankakee River. When in shallow water, they bury themselves in sand or mud and thereby attain almost perfect concealment.

This is a carnivorous species feeding upon crayfish, minnows, insect larvae, frogs, and tadpoles. The food is always caught and swallowed in the water. They have been known to capture game fish by sheer superior agility.

The eggs of this turtle are buried in sand bars close to the water. They are hard-shelled, spherical, and average about a dozen in number.

Although this is a shy, elusive species in its environment, when once captured it struggles vigorously and darts out its head in search of something to bite. The jaws of a large specimen are very sharp and can inflict a painful wound. In captivity, it does well if given a tank with a sand or mud bottom. Rock or concrete soon lacerates the soft plastron and leads to extensive ulceration.

The flesh of this species is eaten in many parts of southern Indiana and is considered by fishermen to be more palatable than that of any other Indiana turtle.

BROWN SOFT-SHELLED TURTLE—*Trionyx muticus* (LeSueur).

Description.—The tubercles are absent from the carapace which is olive or brown in color with obscure dark blotches. The nostrils are round rather than crescent-shaped, and their partition bears no flange.

Size.—Smaller than *T. spiniferus* rarely having a carapace length in excess of 10 inches.

Distribution.—The Ohio Valley and the Wabash and its tributaries as far north as Delphi.

Habits.—This turtle does not differ in habits from the more common spiny soft-shell. Near the junction of White River with the Wabash, I saw dozens of these turtles, as well as *T. spiniferus*, sunning on the steep mud banks. They were very quick to take alarm and scramble into the water.

Like the preceding species, this reptile is often taken for the sake of its meat which is said to be of excellent flavor.

Lizards—Order Sauria

Indiana is inhabited by only a few kinds of lizards; however two species are widely distributed and common. Another species occurs locally in considerable numbers, while two others are of rare occurrence. All of these lizards are small, harmless creatures which feed almost exclusively upon insects and frequent dry sunny places.

Lizards must be distinguished from salamanders which are scaleless, smooth-skinned, and lack claws on their toes. All lizards have movable eyelids and an external auditory opening and, in these respects, differ from snakes. Not all lizards have visible limbs; one species found in Indiana is legless and quite snake-like.

A curious trait of many lizards is their ability to break off all or part of their tail when seized by that member. The severed tail squirms and writhes in a fashion calculated to attract the attention of the would-be captor while the lizard escapes. In most species, a new tail is more or less successfully regenerated. Sometimes injury to the tail or to its growing stump results in the growth of a forked appendage.

Fence Lizards—Family Iguanidae

FENCE SWIFT (Fence Lizard, Wood Lizard)—*Sceloporus undulatus* (Latreille).

Description.—Head fairly wide and chunky with a rounded snout. Body flattened; legs well-developed; tail long and slender. Scales heavily keeled and overlapping.

The color and pattern vary with the sex, activity, and environment of the reptile. Young specimens and adult females are normally a light gray or brown with irregular, wavy, black bands across the back. Adult males are light reddish brown with very little pattern. Cold, damp, or quiescent individuals are very dark. On the chin and belly of males are patches of bright blue bordered with black. Females are largely white beneath with very faint blue markings.

Size.—A small species; adult length 5 to 6 inches.

Distribution.—Very common in the southern part of the state. Recorded from the Dunes area, but Grant thinks it may have been artificially introduced into that locality.

Habits.—This is a lizard of dry, upland situations. Large numbers of them congregate near stone piles, fallen trees, stacks of old lumber, and rail fences. Like most lizards, they are sun-loving animals and are most active on bright days. They are not especially arboreal but often run up tree trunks to escape capture.

A wide variety of insects, chiefly harmful kinds, make up the food of this reptile. Roaches, small moths and caterpillars, squash-bugs and other Hemiptera, ants, saw-flies, bees, and wasps are some of the forms eaten.

Several wild specimens under my observation hibernated in the ground at the base of an old board fence. They were last seen in the fall on November 4, emerged to enjoy two unusually warm days during the last week of January, and resumed their summer activity about the second week of April.

On May 27, I saw two of these lizards rolling and struggling together on the ground. Both escaped before their sex could be ascertained, and I cannot say whether this curious behavior represented courtship or combat. The eggs of the swift are usually laid in a shallow depression scooped out under a log or stone. Sometimes they are buried in loose soil. They vary from 4 to 12 in number and have a thin, parchment-like shell.

If kept warm and dry, this species does well in captivity; although it remains shy and nervous.

Glass-snakes—Family Anguidae

GLASS "SNAKE" (Joint "Snake")—*Ophisaurus ventralis* (Linnaeus).

Description.—Legless and serpentine in form. Head rather narrow and pointed. Tail very long—up to two-thirds of the total length of the reptile. Scales of the back glassy, slightly keeled, and in ring-like rows. Scales of ventral surface smooth and overlapping.

Color olive or brownish thickly speckled with greenish dots which tend to fuse into stripes anteriorly. Underside greenish-white.

Size.—Average adult length 22 inches; diameter $\frac{1}{2}$ inch.

Distribution.—A rare species. Collected by Grant at Jasper-Pulaski State Forest, Dunes State Park, and also in Starke County. I saw a badly-mashed specimen on the highway a mile south of Monon. It probably is found sparingly all along the western border.

Habits.—Not much is recorded concerning the habits of this peculiar reptile. It frequents grassy, open country and feeds upon worms, slugs, insects, and possibly the eggs of small ground-nesting birds.

The popular name comes from the lizard's ability to break off its long tail if picked up or injured. Grant says that specimens "Creak as if about to shatter," when handled. He also mentions that they give off a very unpleasant odor.

Racerunners—Family Teiidae

SIX-LINED LIZARD—*Cnemidophorus sexlineatus* (Linnaeus).

Description.—Head narrow and pointed. Body form slender; tail very long and whip-like. Legs rather long; middle toes of the hind feet extremely thin and elongated. The scales of the dorsal surface of the legs and body are very small and granular; those of the ventral surface larger, rectangular, and polished.

The back is black with six longitudinal stripes of bright sulphur-yellow. The head is light brown or olive with a greenish-yellow tinge to the lip plates. The underside is white, and the legs and tail are light brown. In young individuals, the tail is pale blue.

Size.—Attains a length of 7 to 8 inches of which the tail makes up about two-thirds.

Distribution.—More or less continuously distributed in the sand dune country of northwestern Indiana. In southern Indiana, it is common on the crests of the Bald Knobs from a point about five miles north of New Albany to the Clark County line near St. Joseph.

Habits.—This strictly terrestrial reptile deserves its second popular name of racerunner. It is the speediest of our lizards and the most difficult to capture. Its preference of a very dry, almost arid, habitat explains its absence from most parts of Indiana.

During the hottest days of summer, these little lizards may be observed in continuous, nearly bird-like activity. They scoot aimlessly about occasionally darting out their stubby, forked tongues as do snakes; then they stop to teter up and down on their slender legs or to make curious tapping or shuffling motions with their forefeet. They may sometimes jump into the air to catch insects which they shake terrier-fashion and swallow with much chewing. At night on cool or cloudy days, these lizards take refuge in burrows dug in the sand or clay.

The insects eaten by the six-lined lizard are for the most part small grasshoppers, crickets, and moths.

Hibernation takes place in the same sort of burrow which shelters the lizard during the summer. Grant mentions digging up two of them at Jasper-Pulaski on a cold April day. These lizards are seldom seen out of hibernation before mid-May and return to winter quarters during the first weeks of September.

Little is known of the reproduction of this species. I found six eggs in a female collected June 23. The young begin to appear about mid-August.

In captivity, the racerunner is lively, attractive, and interesting. It must be kept in warm, dry quarters with abundant sunlight; and even then, it is relatively short-lived.

Skinks—Family Scincidae

FIVE-LINED SKINK (Blue-tailed Skink, Scorpion Lizard)—*Eumeces fasciatus* (Linnaeus).

Description.—Head triangular and distinct with a pointed snout. Body moderately stout and slightly flattened. Legs well-developed; tail slightly longer than the body. Scales small and smooth with a high polish.

The color and pattern go through several stages of development as the individual increases in age. The newly-hatched skink is coal-black with five vivid yellow stripes on its back and a bright blue tail. After two or three summers, the blue of the tail fades to gray or light brown, and the stripes become darker, wider, and less distinct. At this stage, the lizard appears brown striped with black and may show a tinge of orange about the jaws. The final stage is reached only by old males. The color now is uniform brown with bright orange-red head and jaws. Females grow very large but retain the stripes and seldom show red about the head.

These color changes do not appear related to sexual maturity; for I have seen females of juvenile pattern that laid fertile eggs.

Size.—Larger and bulkier than any other Indiana lizard. I have seen two specimens that were 8½ inches long and 1½ inches in width. A length of 6 inches is about average.

Distribution.—The entire state but rare in the northern portion.

Habits.—This lizard is common in dry woodland where it is found in company with the fence swift. Also, it shows a predilection for logs, hollow trees, and old buildings. It sometimes enters houses. Not so quick or graceful as the swift or racerunner, it is nevertheless difficult to catch; for it seldom goes far from some favorite hole or crevice. It is an excellent climber and is often seen high on the trunk or larger branches of big trees.

The skink eats a great many kinds of insects especially larval forms. It frequently raids the nests of paper-wasps (*Polistes*), shaking and crushing these structures in an attempt to dislodge the larvae and pupae. Very large skinks may sometimes eat small vertebrates and bird eggs. Miss Edna Banta induced a captive specimen at McCormick's Creek to take earthworms.

On July 26 at Brown County, I found a female skink under a flat stone with her body curled around four eggs. She made no attempt to escape but bit at my fingers. The eggs were incubated in the material in which they were laid, and all hatched on August 2. From this, it appeared that the mother lizard had remained with her eggs throughout the greater part of the incubation period. In Floyd County on August 6, nine newly-hatched skinks were uncovered by splitting a large hollow log. In this instance, the mother was not to be found.

The red-headed form of this lizard is considered very poisonous by many persons. Actually, it is quite innocuous, being unable to inflict any injury more severe than a strong pinch. Compared to other small lizards, this is an easy species to maintain in captivity. It does well in an ordinary terrarium if kept fairly dry. It soon becomes tame and good-natured and will take food from one's fingers.

BRONZE-BACKED LIZARD—*Leiopisma laterale* (Say).

Description.—Head pointed and not distinct from the neck. Body stout and rather cylindrical. Legs short; tail of about the same length as the body. Scales smooth with a dull luster.

Head and central portion of back bronze bordered on each side with a wide black band. Tail light brown; belly yellowish-white.

Size.—A tiny lizard not over three inches in length when adult.

Distribution.—Rare or at least little known in Indiana. I collected two specimens at Brown County State Park and saw another near New Albany. Hay mentions its occurrence in Gibson County.

Habits.—This inconspicuous reptile is probably more abundant than records indicate. All of my specimens were seen in shaded but dry woodland. One was found hiding under a flat stone. It is quick in its movements but wiggles like a salamander instead of running as most lizards do. Its food consists of ants and their larvae and other small insects.

Snakes—Order Serpentes

Few groups of animals are viewed by the public with greater interest and concern than are the snakes. "The way of the serpent upon the rock," has had an appeal to human imagination since time immemorial. Actually, snakes have the same fundamental habits as other reptiles; although they present many curious traits and modifications. It is not my purpose to discuss here the general structure and behavior of serpents nor to correct or explain the numerous strange superstitions and beliefs which have arisen concerning these creatures; although a few of them will be touched upon briefly in the following pages.

Snakes of thirty-two species and three distinct subspecies have been reported from Indiana. Of this number, almost half are very rare or of limited distribution. Three poisonous species inhabit the state.

Parts of Indiana are zones of intergradation for certain species. This is especially true of *Coluber constrictor constrictor* and *Coluber constrictor flaviventris* and of *Lampropeltis triangulum triangulum* and *Lampropeltis triangulum sypila*. Other species intergrading in the state are *Natrix sipedon sipedon* with *Natrix sipedon pleuralis* and *Elaphe obsoleta obsoleta* with *Elaphe obsoleta confinis*.

For sake of convenience, the species of the two families of snakes in Indiana may be divided into several groups for discussion.

Secretive and Burrowing Snakes

(Carphophis, Farancia, Cemophora, and Diadophis)

This series includes three more or less unrelated species similar only in that they prefer a semi-subterranean life. All have smooth scales, conical heads, and small eyes. Only one of these snakes is common in Indiana today; the other two are very rare in the state.

WORM SNAKE—*Carphophis amoenae helenae* (Say).

Description.—Moderately stout. Scales smooth and opalescent. Head not distinct from the neck, wedge-shaped with very small eyes. Tail short and terminating in a sharp spine.

Color deep mahogany to golden-brown above; light to deep pink on the underside. The darker colors are seen in the younger snakes. Adults become grayish-white just prior to shedding their skins.

Size.—Very small; average length 10 inches; diameter 3/16 inch.

Distribution.—Fairly common, although seldom seen, in wooded areas in the southern half of the state.

Habits.—In correspondence with its worm-like appearance, this species is a persistent burrower. It is most often found under logs, boards, and slabs of rock or in the loose soil of shaded hillsides. Occasional specimens may be seen prowling above ground at night or after heavy rains.

Wild and captive specimens appear to feed entirely upon earthworms; however, small slugs and insect larvae may sometimes be eaten.

A nest containing three eggs of this species was found in a rotten log on August 18. It was dug up entire and the eggs hatched September 1. Captive specimens have deposited from 2 to 6 eggs in a clutch usually during the last half of June.

Worm snakes are uninteresting captives; for they soon die unless given some medium into which to burrow. When so provided, they live for months on a diet of earthworms. While handled, they make exploratory movements with their tail, the spine on the end making a pricking sensation which can be very disconcerting to one unfamiliar with the snake.

MUD SNAKE (Horn Snake)—*Farancia abacura reinwardtii* (Schlegel).

Description.—Moderately stout. Scales polished and glossy. Head small and not distinct from the neck. The tail terminates in a needle-like spine.

Lustrous purplish-black above; underside bright red. The red is continued up the sides in a series of blunt bars. Head black on top; reddish speckled with black on the sides.

Size.—Average length is four to five feet.

Distribution.—Recorded more than fifty years ago from near Wheatland in Knox County by a Mr. Ridgeway who collected a specimen and its eggs. There have been no reliable records since.

Habits.—A burrowing, semi-aquatic snake native to the swamps of the southern states. It feeds upon such eel-like amphibians as *Siren* and *Amphiuma*.

In the days when Knox and some of the other southwestern counties were largely covered by cypress swamp, the mud snake probably occurred in fair numbers. It seems to have disappeared with the drainage of the swamps.

SCARLET SNAKE—*Cemophora coccinea* (Blumenbach).

Description.—Form slender and cylindrical. Head not distinct; snout pointed and projecting over the lower jaw. Scales smooth; anal plate entire.

Viewed from above, it appears ringed with wide bands of bright scarlet bordered with black and separated by narrow bands of white or yellow. The ringed appearance is only apparent; for the belly is immaculate white. The snout is red; there is a black band across the eyes and a light patch at the base of the head.

Size.—Average length 16 inches; diameter $\frac{1}{4}$ inch.

Distribution.—The only specimen of this snake taken in Indiana was collected by John Williamson on a hillside four miles west of New Albany on July 9, 1935 and is now in my possession.

Habits.—A secretive, burrowing reptile, the scarlet snake is to be sought under stones, logs and bark. It has been known to feed upon very young mice, small snakes, and young lizards. In addition, it probably eats worms and insect larvae.

Perhaps some of the "coral snakes" sometimes reported from southern Indiana belong to this species. It may be distinguished from the poisonous coral snake by the fact that the bright colors of the coral snake encircle the body while in this species, the underside is unmarked.

RING-NECKED SNAKE—*Diadophis punctatus edwardsii* (Merrem).

Description.—A slender little snake with a flat head slightly distinct from the neck. Scales smooth and satiny.

Color blue-black to gray-brown with a bright yellow or orange collar behind the head. Undersurface yellow to orange with a narrow black border and occasionally a row of black dots down the center.

Size.—Average length 12 inches; diameter $\frac{3}{16}$ inch. The largest Indiana specimen examined was 17 inches long and $\frac{3}{8}$ inch in diameter.

Distribution.—The southern half of Indiana in wooded areas.

Habits.—Cool valleys and shaded hillsides are the favorite haunts of this snake. It is most often found under a stone or beneath the loose bark of a fallen tree but is not infrequently seen in the open. It is not truly a burrower.

I have no notes on the feeding of wild specimens. Captive individuals seem to feed upon almost any small creature they can swallow. Earthworms are the most generally accepted food, but I have seen these snakes eat small salamanders, cricket frogs, and small snakes. One specimen swallowed two young ribbon snakes each only a few inches shorter than it was. I often found ring-necked snakes in and around drying up pools in the canyon at McCormick's Creek where it appeared that they were feeding upon very small minnows trapped in the drying stream-bed.

From 2 to 8 eggs are laid by this species during June or early in July. It has been reported that several of these snakes will use a common nest site.

I have not observed this, but one afternoon I collected five egg-containing females in an area about ten yards square. The following year, two more gravid females were secured in the same place. The eggs of ring-necked snakes hatch in four to six weeks—a shorter period than is required for most snake eggs. There is some evidence to show that the eggs may in rare cases be retained until they are almost ready to hatch.

The Green Snakes (*Opheodrys*)

Two species comprise this group. They are unique among the snakes of the United States in that they are a uniform bright green. They are slender snakes adapted to a semi-arboreal life.

ROUGH GREEN SNAKE—*Opheodrys aestivus* (Linnaeus).

Description.—Very slender with heavily keeled scales. Head moderately distinct; tail long and slender making up one-half to one-third of the total length.

Color leaf-green above; yellowish-white below.

Size.—Average length 26 inches; diameter $\frac{1}{4}$ inch. My largest specimen measured 36 inches. I have seen several nearly as large.

Distribution.—Common in the southern third of the state with a preference for hilly country.

Habits.—One of the few North American snakes which seeks a primarily arboreal habitat. It is most often seen lying on bushes or among vines at heights of two to fifteen feet. It climbs gracefully but deliberately. While climbing, it protrudes its pale orange tongue stiffly and without flickering motion of other snakes.

The green snakes food seems to consist entirely of insects. The longhorn grasshoppers and hairless lepidopteran larvae are most often eaten. Other kinds of grasshoppers, crickets, mantids, and spiders have also been found in the stomachs of green snakes.

Green snakes seldom emerge from hibernation before the last week of April but remain active until late in the fall. This may be of some protective value because their bright bodies would be quite conspicuous against the sparse greenery of early spring. It is equally likely that their autumn activity is correlated with an abundance of suitable insect food at that season.

From 3 to 14 elongated eggs are laid during June or early July. The young begin to appear about mid-September.

The green snake is one of the mildest tempered of serpents and almost never attempts to bite. As a rule, it does not do very well in captivity.

SMOOTH GREEN SNAKE (Grass Snake)—*Opheodrys vernalis blanchardi* Grobman.

Description.—Upon superficial examination looks exactly like the preceding species; however there are the following points of difference; the scales in this species are smooth and satiny while in *O. aestivus*, they are keeled; the ventral surface in this species is white while in *O. aestivus*, it has a yellowish tint; finally, *O. vernalis* is smaller and proportionally a little stouter than *O. aestivus*.

Size.—Average length 14 inches; diameter $\frac{1}{4}$ inch.

Distribution.—Local in northern Indiana. An old record extends the range

south to Brown County. I have collected it only in a small strip along State Highway 43 about one mile south of the Pulaski-Starke county line. Residents say it is the commonest snake in that locality.

Habits.—Like many small snakes, this species occurs in colonies, being numerous in one small area and rare or absent in the surrounding countryside. The factors governing such distribution are not well understood, but probably depend upon an abundance of food plus a desirable hibernating site. Specimens of this green snake are to be sought in damp, overgrown meadows. All of my specimens were found hiding under boards and rubbish. It is not so often seen climbing as the rough green snake.

The food of the smooth green snake consists of insects and spiders. Soft-bodied, hairless larvae seem to be its chief article of diet.

This is usually considered to be an egg-laying species; however there are a few instances in which it has apparently given birth to living young. I have made no observations on the reproductive behavior of this species.

The Hog-nosed Snakes (Heterodon)

These are heavy-bodied snakes with flat, wide, shovel-like heads and sharply up-turned snouts. The teeth in the rear of the upper jaw are much elongated. Their bold markings and peculiar defensive behavior make them easily recognizable. One species is common in that state; a second is somewhat doubtfully reported.

COMMON HOG-NOSED SNAKE (Spreading Viper; Puff Adder; Spread-head; Blowing Viper)—*Heterodon contortrix contortrix* (Linnaeus).

Description.—Body stout; head very distinct with moderately up-turned snout; tail stubby; scales heavily keeled.

The ground color varies from light straw through shades of yellow and orange to brick-red, tan, brown, or grayish. Typically, there is a series of square black or brown blotches down the center of the back and one or two alternating series on the sides. In most adult snakes, the lateral blotches fuse obliterating most of the ground color on the sides. The skin between the scales usually matches the ground color. Head markings are variable, but there are usually wide black bands from the temporal region onto the neck. Belly yellowish heavily suffused with slate-gray; underside of tail conspicuously lighter than the rest of the ventral surface.

A uniform black phase of this snake is seen and is quite commonly taken in Morgan, Monroe, and Owen counties.

Size.—Average length 28 inches; diameter $1\frac{1}{8}$ inch. Our largest specimen measured 39 inches and was $1\frac{1}{2}$ inches in diameter. It was collected near New Washington in Clark County.

Distribution.—The entire state; fairly common in most localities.

Habits.—These snakes are partial to dry woodland or to open country along streams. They do not swim or climb; nor are they often found under rocks or logs.

When surprised, these snakes follow a stereotyped form of behavior by which they have gained a place in American folk-lore as well as in all popular works on nature study. The alarmed snake first inflates its body with air causing its markings to stand out vividly. Then the head and neck are markedly flattened and the air expelled with a loud hiss. The reptile may open its mouth widely and strike in the direction of the annoyance. Should this fail to frighten away the enemy, the snake appears to lose strength, its movements become uncoordinated and convulsive, it writhes and twists grinding its open mouth against the ground, its squirmings become weaker, and finally it rolls on its back, limp and apparently dead. When the danger seems over, the snake lifts its head, turns over, and seeks to escape, only to fall into another paroxysm if alarmed. Moreover, should the limp reptile be placed upon its crawling surface, it betrays its stratagem by promptly rolling over on its back again.

The dynamics of this behavior offer some interesting problems for the student of animal psychology. For instance, is this death feigning more or less under voluntary control, or is it akin to the condition of narcolepsy in the human where the patient becomes unconscious when faced with a difficult or unpleasant situation? Is this response elicited in the snake by the presence of enemies other than man? It is interesting to note that a hatchling snake less than an hour old attempts to feign death when annoyed, but this performance is but a very hasty and inexpert imitation of the adult behavior. It is also interesting that one may pick up the most enraged hog-nosed snake without fear of being bitten, in spite of the fact that the reptile has strong jaws and unusually long teeth.

All the food-containing stomachs of hog-nosed snakes examined contained the remains of toads or frogs. I have not been able to induce captive specimens to take other kinds of food. The prey, which may be very large in proportion to the size of the snake, is swallowed alive. The elongated teeth in the rear of the upper jaw aid in holding the struggling victim.

Captive specimens have laid eggs from June 16 to August 1. The number of eggs in a clutch varied from 6 to 27. Hatching has been observed on August 8 and September 19. The young are about 8 inches long.

Hog-nosed snakes are hardy in captivity and ideal for exhibition or classroom study. They soon lose their eccentric habits; although many continue to hiss loudly when alarmed.

SOUTHERN HOG-NOSED SNAKE—*Heterodon simus* (Linnaeus).

Description.—General form like the common hog-nosed snake. The snout is more prominent and more sharply hooked.

Ground color gray or light brown with square dark blotches down the center of the back and an alternating row down each side. The blotches are smaller than in the common form. The undersurface is yellowish and the tail is not conspicuously lighter than the rest of the ventral surface.

Size.—A smaller, stouter snake than *H. contortrix*. Average length 18 inches; diameter $\frac{7}{8}$ inch.

Distribution.—Reported from southwestern Indiana, without a definite locality.

Habits.—A snake of open, sandy regions. It apparently uses its shovel-like head to aid in burrowing. It bluffs and feigns death in the manner of all snakes of its genus. It is reported to feed upon toads but will not readily take food in captivity.

The Racers (Coluber)

Because of their large size, marked activity, and diurnal habits, the snakes of this group are familiar to nearly everyone who spends much time out of doors. They are all slender snakes with large, smooth scales. Two intergrading subspecies occur in Indiana.

COMMON BLACKSNAKE (Black Racer)—*Coluber constrictor constrictor* (Linnaeus).

Description.—Slender with head moderately distinct; tail long and tapering. Adults are black with a dull sheen above; slate or dark bluish gray beneath; chin and throat white.

The young are gray with dark brown blotches more prominent anteriorly. Their underside is pale gray speckled with brown and reddish.

Size.—Average length 52 inches; diameter $\frac{7}{8}$ inch. A specimen found crushed on a highway near New Albany was 65 inches long and probably represents almost the maximum length attained.

Distribution.—Southern Indiana, intergrading with the blue racer to the north.

Habits.—Blacksnakes are apt to be found almost anywhere that sufficient cover remains for them to survive. They are most common in dry, open woods and overgrown fields. They are very quick and difficult to catch; although their actual speed on such a surface as a lawn is considerably less than that of a man running. They climb well and will sometimes literally shoot to the top of a bush when pursued. They have also been observed to enter the water and swim with ease.

Of eleven food-containing stomachs examined, 6 contained rodents, 5 contained snakes, 1 a tree toad, and 4 contained insects. Nearly all the rodents eaten were mice, as many as five being found in a single stomach. The snakes were all of small, harmless types. Most of the insects were cicadas and large grasshoppers. It is interesting that no birds were found in these examinations; however I have seen these snakes in the act of robbing the nests of song birds. Lizards and frogs are also eaten. A most peculiar choice of food was shown by one specimen found swallowing a young box turtle. The blacksnake is not a constrictor and usually swallows its prey alive. It sometimes holds its food in its jaws and presses it against the ground with a coil while swallowing.

In Indiana, the racers hibernate solitarily more often than not; although group hibernation alone or in company with copperheads, pilot blacksnakes, rattlesnakes, and garter snakes has been reported.

During late April and early May, these snakes are frequently found in pairs; but I have not actually observed mating. Eggs are laid during June and number 6 to 20 in a clutch. They are elongate with blunt ends and look as if they had been sprinkled with coarse salt. I have found nests on two occa-

sions. In each instance, they were under a flat stone on a hillside. The newly hatched young have been taken as early as August 3.

Racers are usually bad-tempered reptiles, striking repeatedly as much as half their length. Their teeth inflict but superficial lacerations. While enraged, they vibrate their tails producing a buzzing sound if among leaves. Most specimens are too nervous to do well in captivity, but an occasional individual will feed readily and become quite tame.

BLUE RACER—*Coluber constrictor flaviventris* (Say).

Description.—General description similar to the preceding form. Adult color olive to gray-green on the back becoming blue-green on the sides. Belly greenish or bluish yellow. Chin and throat yellowish. Young similar to those of the black racer.

Size.—Apparently not as large as the black racer and a trifle heavier. Average length 50 inches; diameter 1 inch.

Distribution.—The zone of intergradation of this species with *constrictor* is debatable. Ortenberger states that *constrictor* does not occur north of Paoli. Springer lists his Marion county specimens as *flaviventris* while Piatt assigns Morgan county specimens to the subspecies *constrictor*. My observations show that there is no appreciable difference in color between racers from Marion and adjoining counties and racers from the Ohio Valley counties. I do not have a typical specimen of *flaviventris* from further south than the southwest corner of Clinton County, but Mr. E. V. Rutherford of Indianapolis has seen a specimen near Danville. Snakes intermediate between *constrictor* and *flaviventris* in color are found in Clinton, Tippecanoe, and White Counties. I have not found any consistent difference in scale characters between racers from northern and southern Indiana.

Habits.—Not essentially different from the black racer. It does not seem quite so speedy. Specimens seen in the marshes of northern Indiana showed no hesitation in taking to the water to escape.

The Rat Snakes (*Elaphe* and *Pituophis*)

Here are included the largest snakes of Indiana and some of the largest species of the United States. They are all constrictors and feed largely upon warm-blooded animals; hence they play a more or less important part in rodent control. They are very strong and muscular and have the crawling surface flat or slightly concave which aids them in climbing and also in constricting prey.

PILOT BLACKSNAKE (Mountain Blacksnake; Cow Snake; Chicken Snake)
—*Elaphe obsoleta obsoleta* (Say).

Description.—Of moderate thickness with the head rather flat, distinct from the neck, and blunt at the snout. Scales feebly keeled with a polished surface.

The newly-hatched snake is gray with H-shaped black blotches on the back and sides. As the snake grows, the light scales of the ground color darken in the center until the pattern is vaguely outlined by dark scales with white, yellow, or orange borders. Occasionally, they appear almost uniformly black.

Some specimens from the southwest tip of Indiana show a strongly blotched pattern even when adult and hence represent intergrades with the gray rat-snake (*E. obsoleta confinis*) of the lower Mississippi Valley. The typical *confinis* does not occur in Indiana.

Size.—Probably the largest snake of the United States with authentic records of specimens over eight feet in length. The longest reported Indiana specimen is one 6 feet 3 inches collected by Hay. Of about 70 specimens examined by myself, the largest measured 5 feet 10 inches in length and $1\frac{1}{2}$ inches in diameter. An Indiana adult of average size is 55 inches long; $1\frac{1}{4}$ inches in diameter.

Distribution.—The entire state exclusive of the northwest corner.

Habits.—A slow-moving snake usually found in forested areas. During the summer, it may frequent grain fields, pastures, and barn yards. It is a good climber and often is seen in trees at heights of fifteen to twenty feet.

Of seven food-containing stomachs examined, one contained a mole, another young rabbits, and two others contained unidentified rodent remains. Three stomachs contained song birds or their eggs, and one contained a young chicken. These snakes sometimes raid hen-houses; and in one case known to us, the marauder came to grief as a result of swallowing a china egg which made him too bulky to escape.

I once watched a pilot blacksnake catch a rat which had taken refuge in a corner behind a barrel. As the snake slid after it, the rat attempted to run out over the reptile's body. Instantly the snake caught the rodent with a fold of its body and pinned it against the wall with force enough to kill it in a few seconds. These snakes are plucky fighters; Blatchley had one that bested a great horned owl.

Pilot blacksnakes are especially numerous in country where there are outcroppings of rock. The snakes hibernate in the crevices in considerable numbers. Seventeen were killed along with several blacksnakes and copperheads in a den uncovered by quarrying operations near Floyd Knobs. During the digging of a railroad cut near Bloomington, a large number of snakes, mostly pilot blacksnakes, were killed by the workmen, who reported them as a "barrel of snakes."

On May 25, two pilot blacksnakes were found in copulation. The female was taken but escaped before her eggs were laid. My records show that the eggs are laid during the last half of July. Six eggs were found in a rotten log, and 13 others were brought to me by a farmer who dug them out of a clay bank. A captive female laid 9 eggs on July 26. The entire group hatched September 25. On September 19, I found three newly-hatched young and the shed skins of several others in an old stump. The eggs of this snake are oval, 1 to 2 inches in length, and have a thick, tough, calcareous shell.

Few large snakes are as satisfactory in captivity as this species. The larger individuals particularly are quiet and docile almost from the moment of capture. A five foot six inch specimen kept at the museum at McCormick's Creek has been handled by literally scores of people, many of them children, over a period of three years without showing any sign of hostility. A plain wooden cage with a pan of water is all that is needed for one of these reptiles. Captive

specimens are fond of soaking for hours in their drinking pans, but I have never seen a wild specimen in the water.

FOX SNAKE—*Elaphe vulpina vulpina* (Baird and Girard).

Description.—Of moderate build with the head fairly distinct from the neck. Scales keeled and in 24 rows; anal plate divided.

Color yellowish-gray with square, black-bordered, rich brown blotches down the center of the back and an alternating series of blotches on the sides. Top of head reddish-brown to orange with a dark cross-band in front of the eyes and another from the eye to the angle of the mouth. Underside yellowish boldly tessellated with black. The fox snake is to be distinguished from the bull snake by its blunt snout in contrast to the pointed snout of the latter.

Size.—An average sized specimen is 45 inches long and 1 inch in diameter. In rare instances, it may exceed five feet in length.

Distribution.—Northern Indiana especially the western portion. If the number of dead specimens found on the highway is any criterion, it must be fairly common in the country between Monon and Medaryville.

Habits.—A snake of pastures, grain fields, and the edges of woods. It is sometimes found in the neighborhood of houses and barns where it searches for the rodents on which it feeds. Like all rat snakes, it is a constrictor. Examples of this snake seen in the field are pugnacious when cornered, vibrating their tails and striking with a short sneeze-like hiss. The popular name comes from the strong, fox-like odor of newly captured individuals.

This is an egg-laying species. I received two newly-hatched specimens about a foot long that had been found in a rotten stump on August 25.

CORN SNAKE—*Elaphe guttata* (Linnaeus).

Description.—General form similar to the other rat snakes. Scales weakly keeled. Ground color gray, reddish yellow, or pink with large crimson blotches bordered with black. Underside white with large black squares.

Size.—Usually three to four feet—rarely larger.

Distribution.—There are old and indefinite records for Brookville and Wheatland and a good record for Mt. Carmel, Ill. just across the state line.

Habits.—A common snake about grain fields in the South, hence the common name. It prefers open country and is often found near houses. It feeds chiefly upon mice and young rats. Its striking colors and gentle disposition make it a popular display specimen.

BULL SNAKE—*Pituophis sayi sayi* (Schlegel).

Description.—Large with a fairly heavy body. Head moderately distinct; snout pointed and projecting over the lower jaw. Scales of the back heavily keeled; those of the sides smooth or lightly keeled.

Ground color yellow to orange with large, square blotches which are black on the anterior portion of the snake, become brown or reddish brown near the

middle, and are again black or dark brown on the tail. On the sides are smaller blotches which tend to run together. Head dark yellow heavily mottled with black. Lip plates white bordered with black. Chin and throat white; abdomen yellowish with large black squares.

Size.—Rivals the pilot blacksnake as the largest Indiana species. *Outdoor Indiana* several years ago published a photograph of a bull snake alleged to be six and a half feet long. A good-sized specimen is 60 inches long and $1\frac{1}{2}$ inches in diameter.

Distribution.—In spite of its large size, this snake has been overlooked by students of Indiana reptiles. It may be a comparative newcomer to the state. My observations indicate it is found along the northwest border and eastward along the Kankakee Valley into Starke County. It is common in Newton County a few miles south of Lake Village.

Habits.—A bold, active reptile, the bull snake inhabits open, sandy prairies and grain fields. When cornered or annoyed, it emits a very loud, rattling hiss. At the same time it vibrates its tail and strikes viciously.

Bull snakes feed largely upon rats, mice, ground squirrels, and young rabbits. Their pointed snouts enable them to force their way into the burrows of their victims. In the western states, they have been demonstrated to be an important factor in the control of destructive rodents; and therefore should be entitled to some protection from unnecessary killing. It is true that they sometimes feed upon ground-nesting birds, young fowls, and eggs; but this is greatly outweighed by their value as rodent destroyers. They are very powerful constrictors; they can squeeze one's wrist with strength enough to obliterate the radial pulse.

About a dozen eggs are laid by this species early in the summer and hatch during late August. A young specimen found September 22 was $22\frac{1}{2}$ inches long.

This snake does well in captivity, subsisting on a diet of rats, mice, and sparrows.

The King Snakes and Milk Snakes (*Lampropeltis*)

The king snakes are moderate-sized, cylindrical, smooth-scaled species. They are all powerful constrictors and feed upon other snakes to some degree. They also eat rodents and are among the most useful of American reptiles.

COMMON MILK SNAKE—*Lampropeltis triangulum triangulum* (Lacépède).

Description.—Slender with the head but slightly distinct from the neck; tail short and rather blunt. Scales in 19-20 rows. Anal plate entire.

Ground color pale gray to grayish-yellow. On the back, a series of 35-50 large saddles which may be light tan, maroon, or dark brown outlined in black. There is a prominent alternating series of blotches on the sides. In the young snake, the blotches are some shade of red. The head is light brown or reddish with a dark patch anterior to the eyes and black band from the eye to the angle of the mouth. On the neck is a light V or Y-shaped mark outlined in black. The belly is white or yellow checkered with black.

Size.—A length of 33 inches and diameter of $\frac{5}{8}$ inch is to be considered average. The largest specimen I examined was 42 inches long and slightly less than an inch in diameter.

RED MILK SNAKE—*Lampropeltis triangulum syspila* (Cope).

Description.—Differs in color and pattern from the preceding form. The blotches in this subspecies are larger and fewer than 35 in number. They extend further down on the sides, and the lateral series of blotches is very small. Viewed from above, this snake appears ringed rather than spotted. The blotches are bright red or orange-red in color. The top of the head is uniform red and the Y-shaped neck mark is absent.

Size.—Generally considered smaller than *triangulum* with an average length of two feet and diameter of $\frac{1}{2}$ inch. A specimen collected in Floyd County measured 38 inches.

Distribution.—In one or the other variety, this snake occurs throughout the state. The two subspecies intergrade in southern Indiana to produce snakes which may have any combination of the characters described under each form. Of a series of 32 specimens collected in Monroe, Owen, Morgan, and Brown Counties, three were typical of *triangulum* and the rest were intergrades. A series of 23 specimens from Floyd and Clark Counties, 13 were typical of *syspila* and the rest intergrades. Three typical specimens of *triangulum* were seen in northern Indiana.

Habits.—Occurring on wooded hillsides, open fields, and suburban lawns, the milk snake shows no preference as to habitat; but in few places is it commonly seen. This apparent scarcity may be explained in part by its secretive disposition. Of 37 collected alive, only two were found in the open; the remainder were coiled under stones, boards, and pieces of scrap metal. The finding of occasional dead specimens on roads suggests that most of their prowling is done after dark.

Mice and young rats are the staple diet of this snake; and it is a fondness for rodents rather than milk that explains its frequent occurrence near barns, sheds, and cellars. Most of our captive milk snakes were fond of lizards; indeed some would eat nothing else. Others showed marked serpent-eating tendencies, and one of them overpowered and ate a small copperhead. The young milk snakes seem to feed chiefly upon small snakes and lizards. Frogs and young birds have been eaten by captive specimens but are probably seldom eaten by the wild snakes.

I have no data on the breeding habits of this snake. It is an egg-laying species and probably is very similar to the black kingsnake in respect to number of eggs and length of the incubation period.

The strikingly-marked specimens of *syspila* and its intergrades are among the prettiest of our snakes. As a rule, they are inoffensive, docile animals; but sometimes they resist handling by biting and holding on with a chewing motion. They vibrate their tails and have been mistaken for rattlesnakes. In captivity, some individuals are hardy; however the majority are delicate and indifferent to food.

PRAIRIE KINGSNAKE—*Lampropeltis calligaster* (Harlan).

Description.—Moderately stout with head slightly distinct from the neck. Tail short and rather blunt. Scales smooth and in 24 rows; anal plate entire.

Ground color light gray to buff or light olive brown. The pattern is variable but usually consists of narrow brown-cross-bands with darker borders. These may be broken into blotches or fused in such a manner as to give the impression of a blotched snake with light longitudinal stripes. The head markings consist of a dark bar across the snout, a similar mark from the eye to the angle of the mouth and an arrow-shaped mark with the point directed rearward on the neck. A dark band runs from the side of the neck to the temporal region. The underside is yellowish checkered or clouded with dark gray.

Size.—An Indiana specimen of average size is 42 inches long and an inch in diameter.

Distribution.—Apparently restricted to the southwestern counties. In Kentucky, it has been taken as far east as Fort Knox.

Habits.—A snake of open prairie but secretive in habits. It seems to spend much of its time prowling along the runways of rodents or hiding under logs or boards.

It seems to feed almost entirely upon mice; although the young of other rodents, as well as birds, lizards, and snakes may be eaten. Like all rodent-destroying snakes, its search for food sometimes brings it close to the dwellings of man.

A forty inch female kingsnake of this type laid 11 eggs on July 22. The eggs were moderately elongated, and several were adherent. They were almost ready to hatch on September 14 when they were accidentally destroyed.

Although generally considered delicate as a captive, I have succeeded in keeping a fine specimen of this snake for the past several months. It feeds readily upon mice and young English sparrows and is very good-natured.

BLACK KINGSNAKE—*Lampropeltis getulus nigra* (Yarrow).

Description.—Of moderate build with the head slightly distinct from the neck. Scales smooth and shining in 21-22 rows; anal plate entire.

The young snakes are glittering black with very narrow but vivid transverse bands of white or yellow which fork and unite on the sides. The light markings are lost to a greater or lesser degree as the snake grows, until most adults are uniformly black with only a few light centered scales to show the original pattern. The head is black lightly dotted with dark yellow; the lip plates are striped with white. The belly is white or yellow heavily checkered with black.

Size.—The usual dimensions for Indiana specimens of this reptile are a length of 40 inches with a diameter of $\frac{7}{8}$ inch. Some specimens are considerably larger. The largest I examined was taken in Owen County and was 54 inches long and $1\frac{1}{4}$ inches in diameter.

Distribution.—Fairly common in the Knobs area and probably throughout southern Indiana.

Habits.—Usually, but by no means always, found in or near dry woodland, this is a bolder, more active reptile than the other Indiana kingsnakes. Its

chief claim to notoriety lies in its fondness for feeding on other snakes. I once collected a large specimen that disgorged a three foot racer and found a small, crushed kingsnake that had swallowed a well-grown Kirtland's snake. My captive specimens have eaten a variety of snakes; although they have little enthusiasm for large watersnakes or hog-nosed snakes. One fifteen-inch kingsnake showed an especially gluttonish appetite swallowing three ten inch snakes in succession. One of my kingsnakes ate a small dead copperhead; another confronted with an average-sized copperhead, attacked it but backed away after receiving a bite on the neck which, incidentally, seemed to cause it no inconvenience at any time. In subduing a snake, kingsnakes use their constricting coils mainly to hold the victim until it can be grasped by the head and swallowed. If the adversary is especially tough, the kingsnake may seize it by the snout and twist its neck several times. Other creatures eaten by the kingsnake include many rodents and some birds and lizards.

I have found these snakes in sexual union on May 8 and 10. In each instance, the female was secured and clutches of 3 and 13 eggs were laid on July 21 and 27 respectively. The eggs were markedly elongated with a tough smooth integument.

In its demeanor toward man, this is generally a docile species; although some specimens strike repeatedly to the accompaniment of sneeze-like hisses. Its rodent and snake eating habits entitle it to protection from ruthless killing. Captive specimens have lived for several years on feedings of mice, snakes, and sparrows.

The Watersnakes (*Natrix*)

As the name implies, these are snakes of semi-aquatic habitat; although they possess no unusual modifications for life in the water. They are dull-colored, rough-scaled, more or less heavy snakes. Most of the Indiana varieties are locally known as "water moccasins" and are believed poisonous. This is fallacious; for the dangerous water moccasin seldom if ever is found in Indiana.

COMMON WATERSNAKE—*Natrix sipedon sipedon* (Linnaeus).

Description.—Stout of body with the head distinct, flattened, and rather triangular. Scales in 23-25 rows, dull and heavily keeled. Anal plate divided.

Ground color tan to dark brown crossed with wide dark bands which tend to break up into upright bars on the posterior two-thirds of the body. Under-side yellowish diffusely flecked and clouded with gray and reddish brown. The very young snakes are pale gray above with vivid black cross-bands. Old specimens may be a uniform dull brown or blackish.

Size.—Average length 32 inches; diameter 1 inch. The largest living specimen measured by us was 45 inches long and $1\frac{3}{8}$ inches in diameter. A dead specimen found in Lake Sullivan at Indianapolis was estimated as having a length of four feet.

Distribution.—Common throughout the state.

Habits.—The security of an aquatic environment plus large broods of living young permit this snake to hold its own in spite of civilization. I have seen large specimens basking along Fall Creek in front of the Indianapolis

City Hospital. Ponds, swamps, rivers, lakes, and creeks of all sizes are frequented by this ubiquitous reptile. Along sluggish, rocky creeks, it is often possible to collect twenty or more watersnakes in a day. The small and middle-sized snakes usually are found under stones or boards near the water; while the large ones live near tangles of roots or piles of driftwood. Nocturnal activity is the rule during the summer.

Fish make up more than fifty percent of the watersnake's diet. The kinds eaten are usually the slower, less valuable species. Some authorities believe that the snakes eat many diseased and dead fish and are useful for that reason. This may be true, but these snakes also destroy a great many small fish not valuable in themselves but as a source of food to the larger fishes. I recall a night on White River in a spot where a huge shoal of small fishes were swimming upstream through weed-choked shallows. Literally dozens of watersnakes were darting among them and catching them without trouble. Watersnakes also eat frogs, toads, salamanders, eels, and rarely, crayfishes and aquatic insects.

I saw a pair of these snakes in copulation in the water, May 29, an exceptionally late date. Young watersnakes are born during the late summer. My earliest date is August 9 and latest September 8. The number of young in a litter averages 20 to 25 but may be much greater. Litters of 60 to 80 young have been reported by reliable observers. An unusually large female which had been in captivity several months unexpectedly gave birth to 6 very much deformed young on August 20. One of these young was only 4 inches long as contrasted to an average of 8 to 10 inches.

Like most watersnakes, this species has a vicious disposition which persists through months of captivity. All of these snakes have a very disgusting odor, and the large ones can inflict a painful bite. Despite these undesirable characteristics, the common watersnake is a hardy captive. It does best if given no water in its cage except a small pan for drinking.

MIDWEST WATERSNAKE (Banded Watersnake)—*Natrix sipedon pleuralis* (Cope).

Description.—Similar in general form to the common watersnake. The ground color is usually lighter being buff or tan, and the bands are narrower and show less tendency to break up on the posterior part of the body. The markings of the ventral surface tend to be arranged in two parallel rows.

Size.—About the same as the common watersnakes.

Distribution.—Southwestern Indiana. The only specimen examined by me came from "the Wabash below Terre Haute." Collection of a large series of watersnakes from southwestern Indiana would probably show this form intergrades with *sipedon* in that locality.

Habits.—Apparently not different from the common watersnake.

RED-BELLIED WATERSNAKE—*Natrix erythrogaster erythrogaster* Forster.

Description.—Dark gray, brown, or blackish with very little pattern. Under-side coppery red. The young are transversely banded with brown or black on a lighter ground color.

Size.—Average adult length about 30 inches.

Distribution.—Of rare and sporadic occurrence. There are good records for Wells and Vanderburg Counties.

Habits.—The peculiar distribution of this southern snake in Indiana and Michigan appears based upon some selectivity in habitat or food. It is a reptile of swamps and shallow ponds rather than open, running water. Investigation of its feeding habits appears to show no essential difference from the common watersnake and throws no light on the problem of distribution. This snake is probably the "black water moccasin" of farmers and fishermen.

DIAMOND-BACKED WATERSNAKE—*Natrix rhombifera* (Hallowell).

Description.—Heavy-bodied with a flat, triangular head. Scales heavily keeled and in 27 rows.

Color olive or brownish with a chain of black markings which enclose rhomboid patches of ground color and connect with upright bars on the sides. Belly yellow with black markings.

Size.—Largest watersnake encountered in Indiana attaining a length of about five feet. A length of 45 inches with a diameter of $1\frac{1}{2}$ inches is average.

Distribution.—A southern watersnake which reaches the southwestern part of Indiana. Blatchley found it in southern Vigo County and cites records from Clay and Morgan Counties.

Habits.—The Vigo County specimens were seen in large ponds near the river. Fishermen along the lower Ohio say they sometimes see unusually large watersnakes basking on bushes and low limbs overhanging the water in shallow inlets. The snakes probably belong to this species.

The food of the diamond-backed watersnake consists chiefly of fish of the slower, bottom-feeding varieties. Frogs, crayfish, and young turtles are also eaten.

This snake looks and is savage. In the places where it occurs, it probably gives rise to reports of "watermoccasins" by persons who claim to know the harmless watersnake. Specimens which I collected in Texas were morose and bad-tempered as captives.

QUEEN SNAKE—*Natrix septemvittata* (Say).

Description.—Rather slender with the head moderately distinct from the neck. Scales heavily keeled and in 17 rows; anal plate divided.

The dorsal surface is a uniform dull brown with traces of three dark longitudinal stripes in some specimens. Down each side on the second and half of the first row of scales is a pale yellow stripe. The belly is grayish-yellow with two longitudinal brown stripes in the central portion.

Size.—One of the smaller watersnakes attaining a maximum length of about 30 inches. An average Indiana specimen is 23 inches long and $\frac{3}{8}$ inch in diameter.

Distribution.—Occurs locally throughout the state.

Habits.—The queen snake is apparently choosy as regards its environment; for it is very common in some streams and entirely absent from others in the same neighborhood. It seems to prefer swift-flowing, rocky streams generously fringed with willows; however it has been reported from lakes and canals. It is especially numerous in Flat Rock Creek near St. Paul and in Fourteen-mile Creek near Charlestown.

It is a timid reptile usually found basking on an overhanging branch or concealed under a rock. It rarely attempts to bite but has the unpleasant odor of all watersnakes.

A dissected specimen had three small crayfish in its stomach, and wild specimens have been observed to feed upon minnows. None of my captive specimens fed voluntarily; although they were offered different kinds of food at frequent intervals.

The young are born during the latter part of the summer. An average-sized female in our collection gave birth to 18 young on July 30.

KIRTLAND'S SNAKE—*Natrix kirtlandii* (Kennicott).

Description.—Moderately stout; head not very distinct from the neck; scales keeled.

Color rusty brown with a row of sooty blotches down the center of the back and a row of small round blotches down each side. The ventral surface is red bordered with rows of black spots. Young specimens are darker above.

Size.—Smallest of the watersnakes with a maximum length of 20 inches. The usual length is 16 inches with a diameter of $\frac{3}{8}$ inch.

Distribution.—Of spotty distribution throughout the state exclusive of the southwestern tip. Prior to the flood of 1937, it was common along Falling Run and its tributaries near New Albany.

Habits.—Although these snakes are usually found near ponds, swamps, or small streams, they are seldom seen swimming. Specimens seen at night along the margins of ponds and ditches rarely seek refuge in the water. Most specimens of this snake are found coiled under boards, pieces of cardboard or metal, or other debris. Few snakes adapt themselves so well to an urban environment. I have found specimens along Pogue's Run slightly over a mile from Indianapolis' Monument Circle.

These snakes are likely to be found where there are large numbers of earthworms, and examination of several reptiles' stomachs showed that they feed largely upon these creatures. Captive specimens rejected small frogs and toads but fed greedily on earthworms and occasionally took very small minnows.

Kirtland's snake appears early in the spring and has been taken at New Albany on March 5. It is seldom seen during the hot months apparently burrowing during the day and prowling by night.

A female in my collection gave birth to six living young on August 7. The little snakes averaged $5\frac{1}{4}$ inches in length.

When disturbed, these snakes flatten their bodies to a remarkable degree but offer no other resistance. In captivity, they seem invariably to do well under terrarium conditions.

The Brown Snakes (*Storeria* and *Haldea*)

The little snakes of this group are not familiar to most people in spite of the fact that they may be found in city parks and suburban back yards. They are secretive but are not true burrowers.

DEKAY'S SNAKE—*Storeria dekayi* (Holbrook).

Description.—Of moderate build with the head fairly distinct. Scales keeled and in 17 rows. Eyes proportionately large.

Light brown or grayish above sometimes with a pale streak down the center of the back. There are more or less numerous black or brown dots which may fuse into very narrow transverse bands. The head is dark on top with a black collar at the base in some specimens. The underside may be white or pale flesh-pink.

The young of DeKay's snake are very dark and velvety in appearance and have a bright yellow collar at the base of the head.

Size.—A small snake with a maximum length of 15 inches. Average length is 12 inches with a diameter of $\frac{1}{4}$ inch.

Distribution.—Found throughout the state.

Habits.—Vacant lots and grassy commons strewn with rubbish or flat stones are the favorite haunts of this little snake. In Indianapolis, I have collected it along Pogue's Run from Brookside Park almost to Michigan Street in a highly urbanized area. In the wilder parts of the state, DeKay's snake is seldom seen but may sometimes be taken in fairly open, rocky situations. It is not often found in the open save during the spring and late fall when specimens are frequently seen sunning themselves upon rocks or pavements.

The food of this species consists almost entirely of earthworms and slugs. Insect larvae and very small amphibians may occasionally be eaten.

A female DeKay's snake collected April 15 and quite stout at that time, gave birth to 11 young on June 26. Since this snake had not been kept with others of its kind during that interval, it would suggest either that fall mating occurs in this species or that the gestation period is unusually short. Other snakes mate during late March or April have their young in late July or August.

This is an utterly innocuous creature. When teased, it will sometimes flatten its body showing white skin between the scales. It has a disagreeable odor but never attempts to bite. Captive specimens take food readily but seem to be delicate and usually succumb to infections or parasites after a few months.

RED-BELLIED SNAKE—*Storeria occipitomaculata* (Storer).

Description.—General form similar to DeKay's snake. Color light chestnut to dark brown sometimes with two parallel rows of small black dots down the back. Head darker than the body. Two prominent yellow spots at the base of the skull. Underside bright red margined with two rows of tiny dark spots.

Size.—Average length 10 inches with a diameter slightly less than a quarter inch.

Distribution.—But few Indiana specimens of this snake are reorded. It has been collected by Blatchley in Vigo County and by Hay in Marion County near Irvington. I have seen three specimens on Silver Hills just outside New Albany, collected another on the Morgan-Monroe State Forest, and found still another dead on a road in Brown County State Park.

Habits.—In Indiana, this seems to be a snake of hilly, forested regions; however, in Michigan and Wisconsin, it may occur in flat or marshy country. My limited observations of the species suggest that it is less secretive than the other small snakes of Indiana. It seems to have a fondness for prowling into thick masses of vines. I found one specimen atop a tangle of poison ivy and another on a window ledge which it apparently had reached by climbing a honeysuckle vine to a height of some fifteen feet.

According to Schmidt and Davis, this snake feeds almost entirely upon slugs. Its tendency to climb may indicate that certain insects and their larvae may be eaten as well.

As with DeKay's snake, the young are born alive and are usually about a half dozen in number.

SMOOTH BROWN SNAKE—*Haldea valeriae elegans* (Kennicott).

Description.—Stout and cylindrical. Head pointed and slightly distinct from the neck; eyes small. Tail short and abruptly tapering. Scales in 17 rows, generally smooth but may show a trace of a keel posteriorly.

Color uniform reddish-brown to gray sometimes with two parallel rows of tiny black dots down the back. Underside yellowish-white. The color of the belly is of value in distinguishing this species from the worm snake (*Carphophis*) in which the belly is pink.

Size.—Length 10 inches or less; diameter $\frac{1}{4}$ inch.

Distribution.—A rare species of southern Indiana. It has been taken from near Mitchell in Lawrence County and from an unspecified location in Brown County.

Habits.—A secretive snake of wooded areas. It feeds upon worms and soft-bodied larvae and is probably nocturnal. A Lawrence County specimen contained several well-developed embryos in its oviducts.

The Striped Snakes (*Thamnophis*)

These are small to moderate sized snakes with keeled scales and undivided anal plates. Nearly all the species have two or three pale longitudinal stripes. Most of them are able to adapt themselves to a variety of environmental situations, and hence are numerous and widely distributed.

COMMON GARTER SNAKE—*Thamnophis sirtalis sirtalis* (Linnaeus).

Description.—Of moderate build; body somewhat flattened; head distinct from the neck. Scales in 19 rows; superior labial plates 7.

Color and pattern are subject to much variation. The ground color may be brown, gray, olive, or greenish with darker spots; or it may be uniform black or dark brown. There are ordinarily three pale longitudinal stripes which

may be any shade of yellow or light green. The lateral stripes are on the second and third rows of scales. The skin between the scales is white. The head is dark and unmarked; the superior labials are lighter. The belly is greenish or yellowish sometimes clouded with dark gray.

Size.—Average length 27 inches; diameter $\frac{3}{4}$ inch. In some places, specimens over two feet are rare; while in more favorable situations, the snake may slightly exceed three feet.

Distribution.—The entire state, common in most places.

Habits.—Unimproved low ground along the outskirts of cities and towns often teems with garter snakes. Here they find an abundance of food, sufficient cover, and a scarcity of natural enemies. In upland districts, the species is less common and is usually found in the vicinity of water. The greatest number of specimens are seen during the spring and fall when they may be found sunning or hiding under rubbish. During the summer, they are seldom seen; since they are most active early in the morning or shortly after dusk. Although not primarily aquatic, they are good swimmers and are often seen in the water. They sometimes climb into low bushes or tangles of vines.

Garter snakes adapt themselves to whatever food is most available in their environment. Specimens found near the Indianapolis Water Purification Plant appeared to be feeding entirely upon earthworms, while examples of the western garter snake (*T. ordinoides vagrans*) collected near the crest of the Continental Divide in Colorado were subsisting upon small fish and rodents. In its ordinary habitat, about 60% of the garter snakes food consists of various amphibians; and about 35% consists of earthworms and fish. Young birds, small rodents, slugs, insects, and crustaceans are sometimes eaten. All food is swallowed alive.

Group hibernation is frequent in this species. One den near New Albany was located in the bed of a drained pond where there were deep crevices in the soil. A den in Indianapolis was situated among piles of rock and tile reenforcing an embankment near the junction of Fall Creek and White River. Snakes of other species often share winter quarters with the garter snake. Garter snakes have been found sunning near their dens as early as March 6 and as late as November 27 in southern Indiana. Mild weather will sometimes tempt specimens out in mid-winter.

Mating in this species has been observed on April 7, 16, and 17. Captive males showed obvious interest in females during the fall, but copulation was not observed. Captive females have given birth to young on July 21, August 7, and August 15. The number of young in a litter varied from 6 to 38. Litters of as many as 70 young have been reported.

Newly-captured garter snakes bite and give off a highly offensive odor but soon become tame. They are easily maintained in captivity and may even be taught to eat hamburger. Like most snakes, they do best in dry quarters.

Several fairly constant color varieties of the common garter snake occur in Indiana. Some of these have been recognized at times as subspecies. In one form, the central stripe is lacking, and the snake appears gray or olive with darker spots. In another variety, the lateral stripes show an orange or red tint anteriorly and the ground color is quite pale. These snakes may be related to

the western variety *parietalis*. There is also a melanistic form in which the snake is black with indistinct olive-green stripes.

PLAINS GARTER SNAKE—*Thamnophis radix* (Baird & Girard).

Description.—Fairly stout with the head moderately distinct from the neck. Scales in 19 rows; superior labial plates 7 or 8.

The pattern differs from the common garter snake in that the lateral stripes are on the third and fourth rows of scales while the central stripe is wide and usually orange in color while the lateral stripes are pale yellow.

Size.—Average length 30 inches; $\frac{7}{8}$ inch.

Distribution.—Common in the suburbs of Chicago. Since there are no natural barriers and this is a prolific species, it doubtless ranges into the northwest corner of Indiana; however the extent of its range in the state is unknown.

Habits.—Apparently not much different from those of the common garter snake. Its feeding habits are dictated by the terrain in which it is found. It seems to thrive in the proximity of civilization but is also common on the wide plains of the West. Specimens sent us from near Chicago were more timid and docile than comparable examples of the common garter snake and were less easily induced to feed.

BUTLER'S GARTER SNAKE—*Thamnophis butleri* (Cope).

Description.—Moderately stout with the head small and not very distinct from the neck. Scales in 19 rows; superior labials 6 or 7.

The ground color is blackish or brownish and the stripes are sharply defined. The lateral stripes are broad and occupy all of the third and part of the second and fourth rows of scales. The ventral scutes are greenish-yellow tipped with black.

Size.—Smallest of its group with a maximum length of two feet. An average specimen is 18 inches long and $\frac{1}{2}$ inch in diameter.

Distribution.—Apparently restricted to the northern half of the state. Blatchley reported it from Turkey Lake and from near Waterloo and Richmond. Evermann and Clark collected a specimen at Lake Maxinkuckee. Springer lists it from Marion County, and Grant found a specimen on a road five miles north of Valparaiso.

Habits.—More secretive than the other striped snakes. It is found in large colonies, occurrence between these colonial zones being very unusual. No choice of habitat is mentioned by workers on Indiana herpetology.

Its most unusual trait seems to be its method of progression. When alarmed, it throws its body into a series of lateral loops and moves from side to side rather than straight ahead. It appears awkward in the open but moves quite rapidly in the grass.

The food of this garter snake consists primarily of earthworms; although small frogs, toads, salamanders, and fishes may be eaten.

The young are born alive usually in numbers of less than a dozen.

This is a very timid, inoffensive snake. It is said to do well in captivity.

RIBBON SNAKE—*Thamnophis sauritus sauritus* (Linnaeus).

Description.—Very slender with a moderately distinct head and long, tapering tail.

Color velvety black with three bright yellow stripes. The lateral stripes are on the third and fourth rows of scales. The head is black and the chin, lips, and throat white. The underside is yellowish-white.

Size.—Maximum length about 35 inches. A female specimen of average size is 26 inches long and $\frac{3}{8}$ inch in diameter.

Distribution.—Most common in northern Indiana but has been found in Vigo and Owen Counties in the southern zone.

Habits.—During mid-summer, these attractive little snakes are often seen in the marsh at Jasper-Pulaski Forest. They frequent the smaller pools and ditches where they are sometimes seen in the water twined among the lily pads. More often, they lie in the grass at the water's edge or climb into low bushes. When alarmed, they dart into the water and hide among the aquatic plants. During spring and fall they are found on higher ground and are seen crossing roads apparently en route to hibernating grounds. Freshly-captured specimens bite vigorously but ineffectively and emit a peculiar sweetish odor rather like that of over-ripe fruit.

Captive ribbon snakes feed readily upon small frogs, toads, salamanders, and minnows. It is likely that the wild specimens subsist upon similar fare.

The litters are small as compared to the other striped snakes. Two captive females bore litters of four young each on July 23 and August 7.

The Black-headed Snakes (*Tantilla*)

The snakes of this genus belong to the family *Boigidae* or the rear-fanged snakes. They have rigid, grooved fangs in the rear of the upper jaw. The larger rear-fanged snakes are mildly poisonous, but the snakes of the genus *Tantilla* are so small as to be completely harmless to man. The black-headed snakes are small, smooth-scaled, secretive reptiles confined to the southern and southwestern states.

The inclusion of a snake of this genus among the reptiles of Indiana rests on the finding of two specimens by the writer and Mr. Frank Powell of New Albany. Unfortunately, both specimens have been lost.

The first specimen was a half-grown individual about six inches long and scarcely thicker than a wooden match. It was found October 16, 1933 at the base of a rock outcrop near Renn's Spring some five miles north and slightly west of New Albany. It was taken alive but died after a few days and was discarded unclassified. A second specimen was found under a stone on Barrel Chute Hill near the northeast corner of Floyd County on May 29, 1938. It appeared to be an egg-containing female; so it was kept alive awaiting the deposition of its eggs. During that time, it contrived to escape but not until it had been examined and studied with some care. These snakes closely resembled *Tantilla coronata coronata*; however the light collar of that species was ill-defined.

I include this species provisionally as a challenge to future collectors. Undoubtedly a careful, persistent search will reveal other specimens.

BLACK-HEADED SNAKE—*Tantilla coronata coronata* (Baird & Girard).

Description.—Slender and cylindrical with a moderately long tail. Head flat and slightly distinct from the neck. Scales smooth and in 15 rows. Anal plate divided. Loreal plate absent. Eyes small with round pupil.

Body uniform pale brown; snout and top of head black. An indistinct light band crosses the tips of the parietal shields at the base of the head and is bordered in the rear by a black band. The belly is pale flesh-pink.

Size.—Very small. Length of adult specimen $11\frac{1}{2}$ inches; diameter $3/16$ inch.

Distribution.—Known in Indiana only from the Knobs near New Albany.

Habits.—Our specimens were taken on dry, barren clay slopes with outcroppings of shale and sandstone. This same country, incidentally, is the home of the six-lined lizard (*Cnemidophorus*). The black-headed snake is secretive and probably nocturnal. Nothing is known of its feeding habits. Tantillas generally feed upon centipedes and insect larvae.

This is presumably an egg-laying species. It and its young are doubtless choice morsels for young racers and kingsnakes; and this may, in part, account for its rarity.

The Venomous Snakes of Indiana

Venomous snakes are relatively rare in Indiana. In the more populous areas, they are virtually unheard-of; nevertheless they do occur and often unexpectedly. The poisonous snakes of Indiana are the copperhead, the massasauga, and the timber rattlesnake. It is unlikely that other venomous species occur; however there is a very old record of the coral snake (*Micrurus fulvius fulvius*) from near Milan in Ripley County. Likewise, the possibility of the cottonmouth moccasin (*Agkistrodon piscivorus*) being found along the sluggish waterways of Posey County cannot be excluded. Naturalists in southern Indiana should familiarize themselves with these two snakes and report any specimens observed.

I estimate that there are about four cases of poisonous snake bites in Indiana annually. Of this number, very few are fatal; and some are so mild as to recover without medical aid. I know of five fatal cases of snake-bite that have occurred in the state. In two cases the snake at fault was a timber rattler; in one case a copperhead; in one case a massasauga; and in one case the type of snake was not determined with certainty. In three of the fatal cases, the victim was a child. Many snake-bites result from fool-hardiness or failure to recognize dangerous reptiles and hence may be prevented by a little care and knowledge. I believe this is a better method of prevention than the indiscriminate killing of snakes in which the innocuous species suffer with the venomous ones.

All of the venomous snakes of Indiana belong to the family of pit vipers or *Crotalidae*. They may be recognized by the presence of a deep pit between the eye and nostril, the elliptical or cat-like pupil of the eye, and the arrangement of the plates under the tail in a single row. All of these snakes possess movable, hollow fangs in the anterior part of the upper jaw. The danger of a bite is in direct proportion to the size of the snake because of the longer fangs and greater quantity of poison injected.

The Moccasins (*Agkistrodon*)

These are pit vipers in which the top of the head is covered with large shields and the tail does not terminate in a rattle. One species is found in Indiana.

COPPERHEAD—*Agkistrodon mokasen cupreus* (Rafinesque).

Description.—Body stout; head fairly wide and definitely triangular; neck slender. Scales keeled.

Ground color light coppery-orange or hazel with dark brown cross-bands of an hour-glass shape. Head coppery on top, lighter on the sides. Underside pinkish-brown margined with large sooty spots. Tip of tail black. The pattern is quite constant; however, the shade of the ground color varies. Occasional specimens are quite dark and the contrasting markings are not vivid.

Three harmless snakes are likely to be confused with the copperhead. They are the hog-nosed snake, the common watersnake, and the milk snake. The copperhead differs from the hog-nosed snake in that it never hisses or flattens its neck when approached, nor does it have dark markings on the head or neck. Habitat usually helps in distinguishing the copperhead from the watersnake; moreover, the watersnake's pattern is the reverse of the copperhead's and is less regular. The milk snake differs in being much more slender with smooth scales and a small head.

Size.—Average length 30 inches; diameter $1\frac{1}{4}$ inches. Our largest specimen was 40 inches long. A specimen seen in Brown County was even larger and was estimated as being nearly four feet long.

Distribution.—Southern Indiana in hilly localities; north in the western part of the state to Fountain County.

Habits.—This appears to be the commonest poisonous snake of Indiana. It is found in considerable numbers in those parts of the state where there is woodland with outcroppings of rocks. In favorable terrain, it is a difficult species to eradicate. A few are still found in the thickly-populated hills just outside New Albany.

The copperhead is one of the most gregarious of our snakes. In addition to hibernating in groups, copperheads are frequently found in pairs or threes during the summer. Several times I have found two or more of these snakes within a hundred feet of each other. During the hot months, copperheads prowl chiefly by night. Their wanderings often take them into woodpiles, tumble-down buildings, barns, and even cellars. In such places, they may be accidentally touched or stepped upon.

Copperhead bites make up about 80% of the cases of snake-bite seen in Indiana. Although exact figures are not available, a conservative estimate would probably be two or three cases per season. Fatalities are very unusual.

A copperhead in the open will almost invariably try to escape; but if cornered or surprised in a hiding-place, the snake may strike with unexpected swiftness. The temper of wild specimens varies. Some have been touched or even trodden upon without attempting to bite, while others apparently strike upon very little provocation.

The digestive tracts of two copperheads dissected by myself contained the remains of small rodents, probably mice. A third specimen disgorged a large fence swift (*Sceloporus*). Frogs, insects, and the young of ground-nesting birds are sometimes eaten by this snake.

Captive female copperheads have given birth to litters of 5 to 11 young during the period from August 22 to September 9. The young are marked like the parent save that they have bright yellow tails.

I have kept a number of these snakes in captivity. Most of them are reluctant to feed at first, but nearly all will eventually take such food as mice and young sparrows. The young will eat small frogs. If not teased, they become sluggish and good-natured.

The Rattlesnakes (*Sistrurus* and *Crotalus*)

These snakes are unique in that their tails terminate in a series of loosely interlocking horny segments which produce a buzzing sound when the tail is vibrated. A new segment is added each time the snake casts its skin, an event which happens two to three times a season. However, rattles of ten or more segments are broken as the snake crawls about; so the rattle is seldom any indication of the owner's age.

All of the rattlesnakes have keeled scales and heavy bodies. They are strictly terrestrial in habits.

MASSASAUGA (Swamp Rattler; Prairie Rattler)—*Sistrurus catenatus catenatus* (Rafinesque).

Description.—Quite stout. Head distinct from the neck but not markedly triangular. Top of head covered with large shields. Rattle relatively small.

Color grayish-brown sometimes with a ruddy tint toward the tail. On the back and sides are large, round dark-brown spots with black margins. These assume the form of rings on the tail. A light line extends from below the eye to the throat. The belly is pale gray heavily marbled with black. Uniformly black specimens of the massasauga are occasionally seen.

Size.—Average length 24 inches; diameter 1 inch. Specimens more than 30 inches long are rare.

Distribution.—The northern fourth of the state, fairly common in some places. I have heard reports of an isolated colony of small rattlesnakes in the strip mine country near Dugger. This is far south of the usual range of the massasauga in the United States.

Habits.—This is a snake of swampy woodland and damp meadows; although there is no evidence that it ever enters the water. During the summer, it is not infrequently seen in grain fields. Because of its small size, this rattlesnake is not so readily exterminated as the larger species.

Those who know this snake well say it is inclined to be pugnacious and is quick to strike. The sound of its small rattle resembles the buzzing of an insect. Cases of massasauga bite are not rare in places where the snake is common.

The bite is seldom very serious; however Lyons and Bishop reported the case of a child who died in a week as a result of a bite on the finger.

The food of the massasauga consists of mice, frogs, and young birds. A specimen examined by Lyons and Bishop had a large meadow mouse in its stomach.

Although these snakes tend to be found in large colonies, no mention is made of group hibernation.

The young are born alive during the late summer in litters of less than a dozen.

I have had little experience with this species in captivity. It cannot readily be induced to take food.

TIMBER RATTLESNAKE (Banded Rattlesnake; Mountain Rattler)—*Crotalus horridus horridus* (Linnaeus).

Description.—Body stout. Head wide and distinctly triangular. Top of the head covered with small scales instead of shields. Scales of the body large and heavily keeled. Rattle well developed.

Ground color sulphur-yellow, buff, or tan becoming darker posteriorly. The tail is black. Crossing the back are wavy or chevron-like black bands narrowly margined with white or yellow. The head is pale and usually unmarked. Some specimens show a yellowish or rusty streak down the center of the back. Other individuals are a uniform velvety black.

Size.—This snake grows quite large in Indiana. The largest one I examined was 58 inches long and 2 inches in diameter. A specimen from Crawford County exhibited at the Indiana State Fair was said to be six feet long. A more average-sized specimen is 44 inches long and 1½ inches in diameter.

Distribution.—Once found in timbered areas over the entire state, it has now been exterminated over much of its range. I have seen it in Morgan, Monroe, and Brown Counties and have recent reliable reports for Clark, Orange, Crawford, and Martin Counties.

Habits.—This impressive creature is an inhabitant of rocky, wooded, hill-sides seldom disturbed by man. During the summer, it may sometimes be found in overgrown fields and orchards or near abandoned buildings.

Although well able to deliver a fatal dose of venom, this snake's habits are such that accidents are rare. It seeks to avoid contact with man, and even when taken unaware, usually sounds its rattle before striking. From newspapers and local reports, I have collected six cases of timber rattle-snake bite from Indiana within fairly recent times. Two of these were fatal. Two of the cases resulted from foolhardy behavior on the part of the person bitten and can scarcely be ascribed to the viciousness of the reptile.

These snakes feed upon small mammals ranging in size from mice to fair-sized rabbits and squirrels. They also eat ground-nesting birds and their eggs. I have observed that captive poisonous snakes strike rodents and do not touch them again until they are dead; while they seize birds and hold them until struggling ceases. Apparently the snakes fear the bites of rodents. Most

of this snake's hunting is done at night. Mr. Griffith, formerly of the Morgan-Monroe State Forest says that most of the rattlers he saw there were crossing roads late in the evening.

Gregarious hibernation in crevices in the rocks seems to be the rule. Farmers in the wilder parts of the state tell of destroying as many as fifty rattlesnakes at one den.

I know nothing of the reproductive behavior save that the young are born during the latter part of the summer and usually number less than a dozen in a litter.

Captive specimens rarely eat and therefore are short-lived. If caught without injury and kept quiet with a minimum of teasing, they may be induced to take mice, rats, sparrows, and similar food and will eventually become quiet and docile.

Those who malign the rattlesnake would do well to consider that it is not a wanton killer, nor does it attack without warning. Instead of a symbol of evil, it should be considered a grim rear-guard of a vanishing wild America.

REFERENCES

- BISHOP, S. C. 1943—Handbook of Salamanders—the salamanders of the United States, of Canada, and of Lower California. Comstock Pub. Co., Ithaca, N. Y. Pp. xiv+555, 144 figs., 56 maps, 1 pl.
- HAY, O. P. 1892—The Batrachians and Reptiles of the State of Indiana. Indiana Dept. Geol. Nat. Resources, Ann. Rep. 17:409-602, pl. 1-3.
- MYERS, GEORGE S. 1926—A Synopsis for the Identification of the Amphibians and Reptiles of Indiana. Proc. Indiana Acad. Sci. 35:277-294, fig. 1.
- SCHMIDT, K. P., AND D. D. DAVIS. 1941—Field Book of Snakes of the United States and Canada. G. P. Putnam's Sons, New York, N. Y. Pp. xiii+365, 35 pls., 103 figs.
- STEJNEGER, LEONARD, AND THOMAS BARBOUR. 1943—A Check List of North American Amphibians and Reptiles, 5th Ed. Bull. Mus. Comp. Zool. 93:1-260.
- WRIGHT, A. A., AND A. H. WRIGHT. 1942—Handbook of Frogs and Toads—the Frogs and Toads of the United States and Canada. Comstock Pub. Co., Ithaca, N. Y. Pp. xi+286, 88 pls.

Notes on Amphibians and Reptiles from the Central United States

John C. Marr

From March through October, 1942, herpetological collections were made along the 100th parallel and west to the 103rd, from the International Boundary in Texas, through Oklahoma and Kansas, into Nebraska. A few specimens were taken in New Mexico, Colorado, and South Dakota. In addition to the 499 specimens collected by the writer, John W. Anderson collected 21; John Davis, 6; Earl S. Herald, 267; Stanley G. Jewett Jr., 32; and Charles G. Sibley, 27; making a total of 852 specimens. Thanks are due all of these for the permission to include their material in this report, as well as for the privilege of examining their field notes. All specimens have been catalogued and complete data may be found in the Natural History Museum, Stanford University.

Herpetological collecting was incidental to other work and time available for this purpose, as well as for recording field observations, was limited. For this reason many of the amphibians and nocturnal reptiles present in the area covered were not secured. In spite of the opportunistic nature of the collecting, several little known species and interesting records were obtained, especially in Texas. With few exceptions, all amphibians and reptiles encountered were collected. Large or abundant species, such as *Terrapene ornata*, *Pituophis s. sayi*, and *Coluber flagellum testaceus*, were collected selectively. All extremely small *Terrapene* were preserved and at least one specimen was taken from each general locality visited. All specimens of all three species were saved when taken near the limits of their ranges.

Under each species, in the following account, the states in which they were taken, with the number taken, are listed from south to north. Counties are listed alphabetically under the states and each is followed by the number taken in that county and date, or dates. All specimens were collected in 1942. Specific localities within counties and SNHM catalogue numbers have been included only for range extensions or for rare forms. An attempt has been made to (1) include as much natural history data as possible; (2) to provide additional descriptive material on rare species, when warranted by the variation of these specimens from previous descriptions; (3) to provide data for the definition of ranges and to point out range extensions (no attempt has been made to mention new county records, although most of the distributional papers on this region by Burt, Ortenburger, Smith, Strecker, Taylor, etc., have been referred to); and (4) to make available lists of series taken, which other workers may wish to examine. All data are from the writer's field notes unless otherwise stated. Collector's names have been included only with those specimens for which complete data and catalogue numbers are given and only if not collected by the writer.

In general, the nomenclature of Stejneger and Barbour's (1943) checklist has been followed. However, important works prior to that date have been consulted.

Unless otherwise indicated all measurements are from formalin-fixed, alcohol-preserved material and were made with dividers to the nearest whole millimeter. Snakes were measured directly on a millimeter rule. Anatomical distances as herein used may be defined as follows: The body length of toads is the distance from the tip of the snout to the most posterior part of the body. The body length of lizards is the distance from the tip of the snout to the anus. The total length of snakes is the distance from the tip of the snout to the end of the tail, and the tail length is the distance from the anus to the end of the tail. The length of turtles is the median length of the carapace and the width of the carapace is taken at the posterior edge of the sixth marginal shields. Egg measurements are the least and greatest diameters.

Ambystomidae

Ambystoma tigrinum mavortium Baird

TEXAS: One; Motley, 1, Oct. 17.

KANSAS: One hundred fourteen; Grant, 1, Aug. 25; Hamilton, 111, June 1; Wallace, 2, June 19.

The specimen from Matador, Motley Co., Texas, was taken at night, after several days of heavy rains, from a puddle in the gutter. One hundred eleven larval salamanders from Hamilton Co., Kans., (Herald) were seined from mud pools adjacent to the Arkansas River near Syracuse. Mud turtles (*Kinosternon flavescens*) cyprinids, and cyprinodonts were all taken from the same pools.

Scaphiopodidae

Scaphiopus bombifrons Cope

KANSAS: Four; Hamilton, 1, May 29; Lane, 2, Aug. 26; Thomas, 1, Aug. 11.

NEBRASKA: Three; Deuel, 1, July 20; Lincoln, 1, July 22; Red Willow, 1, July 2.

The five specimens from Hamilton and Lane Co's., Kansas, and Lincoln and Red Willow Co's., Nebr., were all taken in mouse and rat traps baited with rolled oats. Some had obviously sprung the traps by accidentally disturbing the treadle. Others, judging from their positions in the traps, had been attracted by insects on the bait or by the bait itself. All were taken in fairly dry areas; some near freshly plowed fields.

Bufo

Bufo cognatus Say

KANSAS: Fourteen; Finney, 1, June 1; Ford, 2, May 26, 28; Meade, 1, May 19; Norton, 4, June 19; Seward, 1, May 20; Thomas, 3, June 8, 9; Trego, 2, Aug. 6, 8.

NEBRASKA: Nine; Deuel, 1, July 20; Hitchcock, 8, July 9.

Two of these toads were taken at night under streetlights in Dodge City, Ford Co., and Wakeeney, Trego Co., Kans.; two were taken in the Arkansas and Cimarron River bottoms; and one was caught in a rat trap in Deuel Co., Nebr. Smith (1934: 442) records this toad from "... North Dakota south on the east through central Kansas..." These western Nebraska localities may constitute an extension of the known range, although Wright and Wright (1942: 76) list it from adjoining states.

Bufo compactilis Wiegmann

TEXAS: Four; Pecos, 3, April 24; Sutton, 1, April 29.

The specimen from Sutton Co. was taken in a moist burrow under a rock.

Bufo woodhousii woodhousii Girard

OKLAHOMA: Forty nine; Beaver, 48, Aug. 30, 31, Sept. 1, 7, 8; Harper, 1, May 16.

KANSAS: Forty-one; Ellis, 3, Aug. 4; Finney, 2, June 1, 2; Graham, 9, June 6, 8, 9, 11, 12, 13, 17; Hamilton, 2, June 1; Ness, 2, Aug. 27; Norton, 5, June 19, 23, 24, July 30, 31; Phillips, 1, June 24; Rush, 1, Aug. 17; Trego, 9, Aug. 8, 13; Wallace, 7, June 9.

NEBRASKA: Eleven; Dawson, 1, July 14; Dundy, 1, July 28; Hitchcock, 2, July 6, 7; Lincoln, 5, July 14, 16; Logan, 2, July 17.

This toad was taken in grassland, sand hills, near creeks, and in towns. They were common under streetlights on hot nights, particularly in Beaver, Beaver Co., Okla., where as many as eight or more were observed under one light. The stomachs of those taken under streetlights were crammed with insect remains, largely beetles. Two were taken in rat traps and one was removed from the burrow of a kangaroo rat (*Dipodomys ordii*). The largest specimen was 99 millimeters in length. Nine young ranging from 16 to 32 millimeters were taken between June 8 and August 13 in Kans. and Nebr.

*Hylidae**Acris crepitans* Baird

TEXAS: Forty-seven; Briscoe, 3, Oct. 9; Sutton, 12, April 16, 22; Tom Green, 12, April 26, 28; Val Verde, 9, March 31, April 2; Wheeler, 11, Sept. 14.

OKLAHOMA: Twenty-five; Beaver, 25, July 5, 6.

KANSAS: Seven; Sheridan, 6, Aug. 10; Trego, 1, Aug. 3.

These frogs were invariably found near ponds and streams and generally on sandy banks. They seemed reluctant to enter the water and would hop along the shore in preference to entering the water. When forced to jump into the water they immediately returned to the shore. After several hops they seemingly tired and were more easily captured.

*Leptodactylidae**Syrrophus marnockii* Cope

TEXAS: One; Sutton, 1, April 23.

This specimen, SNHM 7644, was taken two miles north of Sonora under a large, flat piece of limestone. It had rained the night before and the ground was quite moist.

*Ranidae**Rana catesbeiana* Shaw

TEXAS: Three; Wheeler, 3, Sept. 14, 15.

OKLAHOMA: Four; Beaver, 4, Sept. 5, 6, 11.

KANSAS: Two; Trego, 2, Aug. 3, 12.

NEBRASKA: Two; Lincoln, 2, July 11.

This frog was never observed very far from water. The young seemed quite wary, but the large adults (two taken) were easy to catch.

Rana pipiens Schreber

TEXAS: Sixty-four; Brewster, 4, April 14, 15, 26; Briscoe, 3, Oct. 9; Donley, 4, Sept. 28, Oct. 6; Gray, 6, Sept. 21; Hemphill, 5, Sept. 17, 18; Jeff Davis, 3, May 3; Pecos, 1, April 27; Roberts, 25, Sept. 18, 19; Sutton, 1, April 22; Tom Green, 5, April 26, 28; Val Verde, 3, March 31; Wheeler, 4, Sept. 14.

OKLAHOMA: Five; Beaver, 5, Sept. 5, 6, 11.

KANSAS: Eight; Ellis, 1, Aug. 4; Ford, 2, May 31; Graham, 1, June 12; Hamilton, 1, May 31; Sheridan, 2, Aug. 10; Trego, 1, Aug. 6.

COLORADO: One; Yuma, 1, July 27.

NEBRASKA: Six; Dawson, 1, July 14; Lincoln, 5, July 11, 15, 22.

These frogs were observed only in or near water in the spring, but later in the summer were also noted in grassy places removed from water. In September, in Roberts Co., Texas, they were found to be exceedingly common in a slight depression near a dry watercourse where nineteen were captured in a short time. Five were taken in rat traps baited with rolled oats.

Iguanidae

Crotaphytus collaris collaris (Say)

TEXAS: Nine; Coke, 1, May 1; Pecos, 1, April 21; Sutton, 5, April 14, 16, 17, 20, 24; Tom Green, 2, April 26, 30.

OKLAHOMA: Two; Beaver, 2, Sept. 12.

These lizards were common where rocky ledges and loose rocks were present, even in isolated "islands" of such habitat. They are extremely fast and when alarmed take refuge under loose rocks. They can be easily captured by quickly turning over rocks and making a hasty grab. They readily bite if afforded the opportunity.

Holbrookia lacerata Cope

TEXAS: Three; Howard, 1, May 5; Tom Green, 1, April 30; Val Verde, 1, April 3.

The specimen from Val Verde Co. was taken in a sandy wash.

Holbrookia maculata maculata (Girard)

TEXAS: Two; Howard, 1, May 8; Presidio, 1, April 20.

OKLAHOMA: Three; Beaver, 3, Aug. 31, Sept. 7.

KANSAS: Eight; Finney, 1, June 2; Ford, 1, May 26; Hamilton, 1, June 1; Morton, 2, May 22; Wallace, 3, June 11.

NEBRASKA: Four; Lincoln, 2, July 16; McPherson, 2, July 24.

These were generally taken in sandy places. One, measuring 29 millimeters (body length), was taken from the gut of a *Coluber flagellum testaceus*, Sept. 7, Beaver Co., Okla. One from Presidio Co., Texas, (Jewett) was taken from a roadrunner (*Geococcyx californianus*)

Holbrookia texana (Troschel)

TEXAS: Three; Howard, 1, May 5; Sutton, 2, April 19, 24.

Urosaurus ornatus ornatus (Baird and Girard)

TEXAS: Five; Sutton, 5, April 16, 17, 23.

These lizards were taken on fence posts and rocks.

Urosaurus ornatus schmidti Mittleman

TEXAS: Four; Presidio, 4, April 15, 19.

Collected (Jewett) around buildings and on fence posts.

Uta stansburiana stejnegeri Schmidt

TEXAS: Seven; Briscoe, 1, Oct. 9; Ector, 1, May 5; Hall, 2, Oct. 10; Pecos, 2, April 29; Presidio, 1, April 24.

These were taken in sand hills, on rocky ledges, and in mesquite flats.

Sceloporus merriami merriami (Stejneger)

TEXAS: One; Val Verde, 1, March 31.

This specimen was taken from a crevice in the limestone bluffs near the Devils River.

Sceloporus floridanus Baird

TEXAS: One; Tom Green, 1, April 29.

Sceloporus poinsettii Baird and Girard

TEXAS: Three; Jeff Davis, 1, May 5; Pecos, 1, April 24; Sutton, 1, April 19.

The specimen from Jeff Davis Co. (Jewett) was taken from the gut of a *Crotalus lepidus lepidus*. The one from Sutton Co. was found beneath a rock in typical *Crotaphytus* habitat.

Sceloporus undulatus consobrinus (Baird and Girard)

TEXAS: Seventeen; Brewster, 1, April 17; Dickens, 1, Oct. 13; Donley, 2, Oct. 3; Ector, 2, May 5; Hall, 8, Oct. 7, 8; Pecos, 1, April 24; Roberts, 1, Sept. 24; Tom Green, 1, April 28.

OKLAHOMA: Two; Beaver, 2, Aug. 31, Sept. 1.

Individuals taken on April 17, Brewster Co., had 8 eggs; April 24, Pecos Co., 9 eggs; April 28, Tom Green Co., 13 eggs; and on May 5, Ector Co., Texas, 13 eggs. The specimen from Tom Green Co. was removed from the gut of a *Coluber flagellum testaceus*. Those taken by me (15) were almost invariably on fence posts.

Sceloporus undulatus garmani (Boulenger)

KANSAS: Two; Meade, 2, May 21.

NEBRASKA: Four; Lincoln, 1, July 24; McPherson, 3, July 24.

The two from Meade Co., Kans., were taken beneath a dry yucca plant. The male was mounted on the back of the female, although actual copulation was not noted. It was cold and the pair were very inactive.

Phrynosoma cornutum (Harlan)

TEXAS: Twenty-six; Brewster, 4, April 17, 25, 26; Ector, 2, May 5; Howard, 1, May 8; Pecos, 14, April 24; Presidio, 2, April 1, 16; Tom Green, 1, April 27; Val Verde, 2, March 29, April 8.

OKLAHOMA: Two; Beaver, 2, Aug. 30, Sept. 6.

Seven young specimens of the following body lengths were taken: 30 millimeters on April 17, Brewster Co.; 31, 32, 33, and 34 mm. on April 24, Pecos Co., Texas; and 24 mm. on Aug. 30 and Sept. 6, Beaver Co., Okla. The first five probably represent young of the previous year (1941) and the last two are probably the young of 1942, if only one brood per year is produced.

Phrynosoma orbiculare hernandesi (Girard)

TEXAS: One; Jeff Davis, 1, May 3.

Phrynosoma modestum Girard

TEXAS: Eight; Brewster, 3, April 17; Pecos, 2, April 24; Presidio, 3, April 3, 20, 22.

The specimens from Presidio Co. (Jewett) were taken in sandy flats and on rocky hillsides.

Teiidae

Cnemidophorus perplexus Baird and Girard

TEXAS: Three; Pecos, 2, May 3; Presidio, 1, May 8.

Cnemidophorus gularis Baird and Girard

TEXAS: Nineteen; Armstrong, 1, Sept. 30; Donley, 1, Oct. 1; Ector, 4, May 5; Howard, 6, May 5, 8; Pecos, 1, May 3; Sutton, 4, April 20, 24; Tom Green, 1, April 29; Val Verde, 1, April 10.

It was noted, in Sutton Co. particularly, that these lizards were generally found in flat grassy places, but occasionally were taken along rocky ledges and under rocks in conjunction with *Crotaphytus*. The latter, however, was never found away from the rocks and in typical *Cnemidophorus* habitat.

Cnemidophorus sexlineatus (Linnaeus)

TEXAS: Two; Ector, 1, May 5; Hemphill, 1, Sept. 22.

KANSAS: Twenty-three; Ellis, 1, Aug. 5; Ford, 9, May 29, 31, June 4; Graham, 1, June 11; Gray, 3, June 3, 4; Meade, 4, May 16, 18; Norton, 2, June 19, July 28; Sheridan, 1, Aug. 10; Trego, 2, Aug. 13.

Individuals taken on June 3 and 4, Gray Co., Kans., had 3 and 5 eggs. Seven young of the following body lengths were taken: 39 millimeters, May 18, Meade Co., tail slightly blue; 36 and 43 mm., May 31, Ford Co., tails with adult coloration; 32 mm., Aug. 5, Ellis Co., tail blue; 2 specimens 31 mm., Aug. 13, Trego Co., Kans., tails blue; and 28 mm., Sept. 22, Hemphill Co., Texas, tail blue. The first three are probably young of the previous year (1941), while the latter four represent young of 1942.

Cnemidophorus tessellatus tessellatus (Say)

TEXAS: Three; Armstrong, 2, Sept. 30; Presidio, 1, April 15.

The two from Armstrong Co. were taken in a sandy wash in Palo Duro Canyon.

Scincidae

Eumeces brevilineatus Cope

TEXAS: Five; Sutton, 5, April 16, 19.

All were taken in the daytime in fallen oak leaves under the oak thickets that grow along the limestone ledges in this region.

Eumeces obsoletus (Baird and Girard)

TEXAS: One; Ector, 1, May 6.

OKLAHOMA: One; Beaver, 1, Aug. 31.

KANSAS: One; Grant, 1, Aug. 29.

The specimen from Beaver Co., Okla., a second year juvenile, was taken from a woodrat (*Neotoma micropus*) "house." The two adults, Ector Co., Texas, and Grant Co., Kans., (Herald) were taken in rat traps baited with rolled oats. Judging from their position in the trap they were interested in the bait or in insects on the bait.

Colubridae

Heterodon contortrix contortrix (Linnaeus)

TEXAS: One; Hall, 1, Oct. 9.

This specimen, SNHM 10392, taken DOR one mile west of Brice, probably approaches the southwestern limit of its range. Ortenburger and Freeman (1930: 182) record it in Oklahoma from "Texas County, 8 miles southeast of Guymon," and Smith and Leonard (1934: 193) from "Harper County, [Okla.] Cimarron River, S of Englewood, Kansas."

Heterodon nasicus nasicus Baird and Girard

TEXAS: Two; Hall, 1, Oct. 9; Martin, 1, May 7.

OKLAHOMA: Two; Beaver, 2, Sept. 2, 9.

KANSAS: Twenty-four; Decatur, 1, June 24; Finney, 2, May 30; Ford, 8, May 27, 28, 29, June 2, 3; Gray, 2, June 4; Hodgeman, 2, June 5; Logan, 2, June 10; Phillips, 1, June 24; Sherman, 1, June 18; Thomas, 1, June 9; Trego, 2, Aug. 3, 14; Wallace, 2, June 11, 18.

COLORADO: Two; Prowers, 1, June 6; Yuma, 1, July 27.

NEBRASKA: Six; Deuel, 2, July 20; Lincoln, 3, July 24; McPherson, 1, July 24.

Eggs were found in May and June in nine individuals. In these, and other snakes, there often occurred numerous small eggs very distinct in size from the larger eggs and distributed in the ovaries with these larger eggs that were obviously to produce young shortly. Either these small eggs had started to develop and for some unknown reason were being resorbed, or they represent a group of eggs that would mature the following year or later in the same year. In all egg counts the small eggs have been omitted. Kansas specimens from Ford Co. taken on May 27 had 14 eggs; on May 29, 23 eggs; on May 29, 11 eggs; on June 2, 17 eggs; on June 3, 7 eggs; from Gray Co. on June 4, 13 eggs; from Logan Co. on June 10, 7 eggs; and from Sherman Co. on June 18, 13 eggs. In a specimen from Ford Co., June 2, a *Bufo* sp. was noted in the gut. Unidentifiable insect remains were noted in others.

Coluber constrictor flaviventris (Say)

TEXAS: Three; Hemphill, 3, Sept. 14, 17, 22.

KANSAS: Ten; Decatur, 1, June 25; Ford, 1, May 26; Meade, 2, May 21; Ness, 2, Aug. 21, 25; Trego, 1, Aug. 13; Wallace, 3, June 9, 17.

NEBRASKA: Two; Red Willow, 2, July 1, 3.

These snakes were generally taken in meadows or grassland. Eggs were found in Kansas specimens as follows: Meade Co., June 21, 17 eggs; Wallace Co., June 9, 8 eggs; Wallace Co., June 17, 5 eggs. The eggs of the latter were somewhat posterior in the oviduct and the shells were well developed; possibly some eggs had already been deposited. Juveniles of the year were taken in Hemphill Co., Texas, on Sept. 17 and 22. One from Meade Co., May 21, had a *Reithrodontomys albescentis* in its gut.

Coluber flagellum testaceus Say

TEXAS: Thirteen; Brewster, 3, April 28, 29; Hemphill, 1, Sept. 23; Motley, 1, Oct. 21; Pecos, 4, April 24, May 1; Sutton, 1, April 16; Tom Green 1, April 25; Val Verde, 2, April 2.

OKLAHOMA: Two; Beaver, 2, Sept. 6, 7.

KANSAS: Seven; Ford, 2, May 26; Kearney, 1, June 4; Meade, 1, May 13; Morton, 1, May 22; Trego, 1, Aug. 15; Wallace, 1, June 17.

This snake was not observed north of Trego Co., Kans. An individual from Morton Co., Kans., May 22, had 11 eggs and one from Wallace Co., Kans., June 6, had four eggs. A specimen from Sutton Co., Texas, April 16, disgorged a *Sceloporus* sp. and two *Sceloporus* eggs; nine additional eggs were found in the snake's gut. A *Sceloporus undulatus consobrinus* was found in the gut of one from Tom Green Co., Texas, April 28. The remains of at least two *Cnemidophorus* sp. were noted in one from Trego Co., Kans., Aug. 15. Two large grasshoppers, a large caterpillar, and a small *Holbrookia m. maculata* were found in a specimen from Beaver Co., Okla., Sept. 7.

Coluber taeniatus schotti (Baird and Girard)

TEXAS: Two; Val Verde, 2, April 2, 10.

One, SNHM 9856, was found DOR on April 2, just west of Sacatosa Creek on Texas Hwy. 85. The other, SNHM 9864, was taken on April 10, crossing U. S. Hwy. 90, 8.5 miles northwest of Del Rio. Both agree closely with Gloyd and Conant's description of *schotti* (1934). From their distributional records SNHM 9864 might be expected to be a *schotti-girardi* intergrade, but such tendencies were not noted. At least two other *schotti* were observed in this vicinity, but their extreme rapidity, terrestrially and arboreally, prevented their capture.

Elaphe laeta laeta (Baird and Girard)

TEXAS: One; Donley, 1, Oct. 2.

This specimen agrees well with Woodbury and Woodbury's (1942) diagnosis of the subspecies. It was taken in the bottom of a ditch filled with blown tumbleweeds. Two very young cotton rats (*Sigmodon hispidus*) were removed from its gut and a nearby nest was found to contain twelve more rats of similar size. The loud "squeaking" of the rats led to the removal of the tumbleweeds and the discovery of the snake.

Elaphe sclerotica Smith

TEXAS: One; Val Verde, 1, April 6.

This snake, SNHM 9855, was found DOR just east of the Devils River Canyon and just south of U. S. Hwy. 90. This locality apparently constitutes a range extension of slightly less than 200 miles east of the Davis Mtn. region (Jeff Davies Co., Texas).

Arizona elegans elegans Kennicott

TEXAS: One; Howard, 1, May 5.

OKLAHOMA: One; Beaver, 1, Sept. 10.

KANSAS: Three; Cheyenne, 1, July 7; Ford, 2, May 27, 28.

All were found DOR except SNHM 10393, collected by John W. Anderson, Cheyenne Co., Kans., thirteen miles southeast of Benkelman, Nebr. This specimen was attempting to eat a trapped (dead) kangaroo rat (*Dipodomys ordii*). This locality extends the known range of this snake some 150 miles to the north. It probably will be found in Nebraska. Previous records in Kansas are from Clark, Morton, and Stafford Co.'s (Taylor, 1929a and b), and Reno Co. (Burt, 1933 and 1935).

Pituophis sayi sayi (Schlegel)

TEXAS: Six; Hemphill, 1, Sept. 24; Howard, 1, May 4; Moore, 1, May 10; Motley, 1, Oct. 12; Pecos, 1, April 29; Sherman, 1, May 10.

KANSAS: Ten; Cheyenne, 1, July 7; Ford, 3, May 26, 29, June 3; Hamilton, 1, May 29; Meade, 2, May 16, 20; Morton, 2, May 15, 22; Norton, 1, June 20.

NEBRASKA: Two; Hitchcock, 1, July 6; Red Willow, 1, July 8.

One specimen was taken in Ford Co., June 3, with 11 eggs. One from Meade Co., May 16, had two young doves (*Zenaidura macroura*) in its gut. One from Norton Co., Kans., June 20, disgorged a white-footed mouse (*Peromyscus maniculatus*). One from Hitchcock Co., Nebr., July 6, had what appeared to be a grasshopper mouse (*Onychomys leucogaster*) and many nematodes in its gut.

Lampropeltis getulus splendida (Baird and Girard)

NEW MEXICO: One; Torrance, 1, May 9.

TEXAS: One; Hemphill, 1, Sept. 23.

SNHM 9833 collected by Stanley G. Jewett Jr., 48 miles south of Vaughn, Torrance Co., New Mexico, was taken somewhat north of the known range of this snake. Blanchard (1921: 28) gives Dona Ana Co. as the northernmost record in New Mexico, but adds that "... it doubtless extends considerably north of Fort Fillmore.... [Dona Ana Co.]." Schmidt and Davis (1941: 178) record it from "... southern New Mexico...."

Lampropeltis triangulum gentilis (Baird and Girard)

KANSAS: One; Ford, 1, May 30.

This specimen, SNHM 9914, was taken at night nine miles east of Dodge City, in a rat trap set near a brushy rock ledge. It is a large individual, measuring $28\frac{7}{8}$ inches in total length (fresh), and contained twelve eggs about 14×24 millimeters (fresh).

Rhinocheilus lecontei tessellatus Garman

TEXAS: Two; Coke, 1, April 30; Pecos, 1, April 21.

The specimen from Coke Co. was found DOR.

Natrix erythrogaster transversa (Hallowell)

TEXAS: Four; Pecos, 3, April 19, 29, May 5; Tom Green, 1, May 28.

KANSAS: Two; Ford, 2, May 28.

Individuals from Tom Green Co., Texas, and Ford Co., Kans., were all taken in streams. A catfish, almost completely digested, was found in the gut of one from Pecos Co., Texas.

Natrix grahamii (Baird and Girard)

TEXAS: One; Hemphill, 1, Sept. 9.

This snake, SNHM 10394, was found DOR near a small "swamp" just north of the Canadian River and 5 miles west of Canadian. This locality is about 125 miles from Comanche Co., Okla., which is apparently the nearest previously recorded locality (Smith and Leonard, 1934: 194).

Natrix harteri Trapido

TEXAS: Two; Tom Green, 2, April 29.

These specimens, SNHM 9896-7, were taken near the South Fork of the Concho River near Christoval. *N. harteri* was previously known only from the types collected along the Brazos River, north of Palo Pinto, Palo Pinto Co., Texas. This new locality is some 165 miles to the southwest and is in the Colorado River watershed. Comparison of these specimens with the types is given in Table 1.

TABLE 1.—Comparison of *Natrix harteri* from the South Fork of the Concho River with the type specimens (data from Trapido, 1941) from the Brazos River.

	SNHM 9897 ♀	SNHM 9896 ♂	23 types (Trapido)
total length	467 mm.	273 mm.	228.6 - 812.8 mm.
tail length	114 mm.	74 mm.	
tail length / total length	24.4%	27.1%	{25.7% - 27.6% ♂, 22.0% - 25.8% ♀
scale rows: neck	23	21	21 - 26
scale rows: mid-body	22	23	20 - 23
scale rows: anus	17	17	16 - 17
upper labials; L, R	8, 8	9, 8	8 - 7, 8
lower labials; L, R	10, 10	10, 10	9 - 11
postoculars; L, R	3, 3	3, 3	2 - 3, 2 - 3
ventrals	143	142	{145 - 149 ♂, 146 - 150 ♀
subcaudals	70	82	{81 - 85 ♂, 71 - 75 ♀
posterior temporals; L, R	1, 1	1, 1	1 - 5, 1 - 4
dorsal body spots	56	55	58 - 65

It can be seen that the Concho River specimens agree with those from the Brazos River, with slight variations. The dorsal body spots, ventrals, and subcaudals are all somewhat fewer than the minimum given for the types. The dorsal coloration and pattern are the same. The venter is largely the same, but no pink was observed (in alcohol). The dark pigment on the anterior $1/3\frac{1}{2}$ of the caudals is evidently more pronounced in the Concho River individuals.

The ecological distinctions between *N. harteri* and *N. e. transversa* made by Trapido (1941) were observed here. The two *harteri* were coiled under one rock on a small (eight square feet) "island." One *transversa* was taken within fifty feet of this island in a small pool left as a bypass from the main stream by receding waters.

Thamnophis eques eques (Reuss)

TEXAS: One; Sutton, 1, April 15.

This snake was found in a dry area beneath a rock along a limestone ledge. The remnants of a small toad (*Bufo* sp.) were found in its gut.

Thamnophis marcianus (Baird and Girard)

TEXAS: Eight; Brewster, 2, April 26, 29; Donley, 1, Sept. 29; Pecos, 1, April 25; Presidio, 1, April 22; Schleicher, 1, April 17; Sutton, 1, April 24; Tom Green, 1, April 30.

KANSAS: Two; Sheridan, 1, Aug. 10; Trego, 1, Aug. 8.

The specimen from Pecos Co., April 25, had 12 eggs. One *Pseudacris (nigrita clarkii?)* was noted in the gut of the snake from Schleicher Co., Texas.

Thamnophis radix (Baird and Girard)

OKLAHOMA: One; Beaver, 1, Sept. 11.

KANSAS: Twelve; Ford, 2, May 27, 28; Hamilton, 1, June 3; Meade, 2, May 16, 20; Rooks, 2, June 11; Sheridan, 1, June 17; Sherman, 1, June 18; Wallace, 3, June 9.

NEBRASKA: Four; Lincoln, 3, July 13, 20, 22; Perkins, 1, July 22.

Eggs were noted as follows: Ford Co., May 28, 17 eggs; Hamilton Co., June 3, 18 eggs; Wallace Co., June 9, 13 eggs; Rooks Co., June 11, 25 eggs; Sheridan Co., Kans., June 17, 37 eggs with the embryos visible; and Perkins Co., Nebr., July 22, 27 embryos 11 to 12 centimeters in total length. A juvenile $9\frac{1}{4}$ inches in total length (fresh) was taken in Wallace Co. on June 9. One was seen eating a dead (trapped) house mouse (*Mus musculus*) and another that was taken from a live bait tank disgorged two small fishes. One was taken in a small pond.

Thamnophis sauritus proximus (Say)

TEXAS: Seven; Pecos, 7, April 19.

KANSAS: Five; Scott, 1, Aug. 20; Sheridan, 4, Aug. 10.

The specimens from Pecos Co., Texas, April 19, measured 318, 327, 346, 356, 357, 366 and 560 millimeters in total length. The first six are probably the young of 1941, while the last one is probably from the 1940, or earlier, broods. One individual from Scott Co., Aug. 20, measured 516 millimeters and those from Sheridan Co., Kans., Aug. 10, measured 516, 226, 243, and 285 millimeters. The last three are of the 1942 brood, while the larger ones from Scott and Sheridan Co.'s. are probably of the 1941, or earlier, broods.

Thamnophis sirtalis parietalis (Say)

TEXAS: One; Hemphill, 1, Sept. 22.

NEBRASKA: Two; Lincoln, 1, July 23; Logan, 1, July 17.

The specimen from Lincoln Co., Nebr., had a grasshopper in its gut.

Hypsiglena ochrorhyncha Cope

NEW MEXICO: One; Taos, 1, May 9.

This snake, SNHM 9834, taken DOR by Stanley G. Jewett, Jr., 2 miles north of Taos, Taos Co., constitutes the second record for New Mexico. Koster (1940) reports it from "... five miles southwest of Los Lunas in Valencia County..." This new locality is some 140 miles to the northeast.

*Boigidae**Tantilla gracilis* Baird and Girard

TEXAS: Two; Sutton, 2, April 13.

These two snakes were taken within a few yards of each other under limestone rocks in a moist situation in a small valley.

*Crotalidae**Crotalus atrox* (Baird and Girard)

TEXAS: Seven; Armstrong, 1, Sept. 30; Brewster, 2, April 28, 29; Cottle, 1, Oct. 16; Howard, 1, May 4; Motley, 1, Oct. 14; Pecos, 1, April 24.

The specimen from Pecos Co., April 24, contained 24 eggs and the one from Howard Co., May 4, had 16 eggs. Two young cottontail rabbits (*Sylvilagus auduboni*) were found in the gut of one; a white-footed mouse (*Peromyscus maniculatus* or *leucopus*) in another; and a tapeworm and unidentifiable mammalian remains in a third. Gloyd (1940) and others do not record this snake from the Texas Panhandle and it apparently is absent from the plains. SNHM 10396, taken in Palo Duro Canyon, 18 miles south of Claude, Armstrong Co., Texas, on Sept. 30, was well into the Panhandle, although definitely not on the plains.

Crotalus lepidus lepidus (Kennicott)

TEXAS: One; Jeff Davis, 1, May 5.

This specimen was collected by Jewett and was not preserved. Two lizards were taken from its gut. One, *Sceloporus poinsettii*, was saved.

Crotalus viridis viridis Rafinesque

TEXAS: One; Roberts, 1, Sept. 23.

OKLAHOMA: One; Beaver, 1, Sept. 2.

KANSAS: Seven; Hamilton, 2, June 2; Logan, 1, June 11; Meade, 1, May 16; Ness, 2, Aug. 24, 27; Thomas, 1, Aug. 12.

A specimen from Hamilton Co., June 2, had 14 eggs and one from Thomas Co., Kans., Aug. 12, contained 14 embryos measuring from 175 to 195 millimeters in total length. One taken in a rat trap in Ness Co., Kans., Aug. 27, had an adult *Microtus haydeni* in its gut.

*Kinosternidae**Kinosternon flavescens* (Agassiz)

TEXAS: Five; Brewster, 1, April 1; Howard, 1, May 9; Motley, 1, Oct. 15; Pecos, 1, April 20; Val Verde, 1, April 10.

OKLAHOMA: One; Beaver, 1, Sept. 5.

KANSAS: Eight; Hamilton, 8, May 31.

These turtles were exceedingly common in mud pools along the Arkansas River, from which those from Kansas were seined. Those from Motley and Val Verde Co's., Texas, were taken while crossing roads, in both instances apparently far removed from water.

*Chelydridae**Chelydra serpentina serpentina* (Linnaeus)

TEXAS: One; Pecos, 1, May 1.

NEBRASKA: One; Lincoln, 1, July 25.

The specimen from Nebraska was taken while crossing the road. Their tracks were very commonly observed in recently dried water courses.

*Testudinidae**Terrepene ornata* (Agassiz)

TEXAS: Ten; Armstrong, 1, Sept. 30; Dickens, 2, Oct. 13; Donley, 2, Sept. 29, Oct. 3; Hemphill, 1, Sept. 15; Howard, 1, May 8; Sherman, 1, May 10; Sutton, 1, April 24; Tom Green, 1, April 29.

OKLAHOMA: Four; Beaver, 1, Sept. 1; Harper, 3, May 16.

KANSAS: Thirty-five; Finney, 2, May 26, 30; Ford, 10, May 27, 28, 29, 31; Hamilton, 12, May 24; Lane, 1, Aug. 25; Morton, 8, May 12, 22; Trego, 2, Aug. 4.

COLORADO: Two; Prowers, 1, June 6; Yuma, 1, June 3.

NEBRASKA: Two; Hitchcock, 1, July 6; Red Willow, 1, July 2.

This box turtle was common where encountered, particularly in the plains and sand-hill regions. On hot days they were most active early and late in the day and during the middle of the day were often observed in holes only slightly larger than themselves. Twenty-one were taken in rat traps baited with rolled oats and had definitely been eating the bait. They were commonly observed eating trapped rodents and one was seen eating a grasshopper.

Copulation was observed twice. In both instances the turtles were seen only after the union had started and the courtship was therefore not seen. The first pair were seen in Ford Co., Kans., on May 29, by Sibley, who found a male *Terrepene* mounted on a dead female which had been killed by a rat trap. The second pair were seen in Dickens Co., Texas, on October 13, but separated before photographs or prolonged observation could be made. The female was in a normal position and the male was standing erect, its plastron against the carapace of the female. The male was leaning back so that their bodies made an angle somewhat greater than 90 degrees and appeared to be resting on its hind limbs and the posterior part of the carapace.

Since the young have not been adequately described (Pope, 1939: 140) a short description of the five young secured will be included. The localities, dates, length (L), and width (W) in millimeters are as follows: Finney Co., May 26, L 37, W 34; Finney Co., May 30, L 31, W 33; Ford Co., Kans., May 31, L 33, W 34; Prowers Co., Colo., June 6, L 35, W 34; and Red Willow Co., Nebr., July 2, L 30, W 28. As will be noted, the young are almost round and not elongated as are the adults. They appear to be relatively flatter than the adults. A rounded dorsal ridge, not a crest, is present in all five specimens. They are darker than the adults; the dorsal ridge is yellow and there are faint light spots on the carapace, but the adult pattern is not yet distinct. The plastron is light margined with no pattern of light spots present in the dark interior.

Graptemys pseudogeographica versa Stejneger

TEXAS: One; Tom Green, 1, April 28.

This specimen, SNHM 9701, taken in the South Fork of the Concho River near Christoval, represents a northwesterly range extension of some seventy-five miles. Previously it has been known only from the type locality at Austin and from northeastern Edwards Co., as reported by Daugherty (1942). The Concho River, at this new locality, is relatively cold and rapid. Due to its coloration and small size this turtle might easily be overlooked and careful collecting will probably extend its known range considerably.

Chrysemys picta bellii (Gray)

NEBRASKA: Nine; Deuell, 9, July.

SOUTH DAKOTA: One; Campbell, 1, June 10.

Pope (1939: 202) states that "Judging by existing records, however, it [*bellii*] avoids all of Oklahoma. . . ." This turtle was observed rather commonly in Beaver Co., Okla., but unfortunately none were secured.

*Trionychidae**Platypeltis*¹ *emoryi* (Agassiz)

TEXAS: One; Wheeler, 1, Sept. 15.

This turtle is apparently referable to this species, although comparative material was not available. It was compared with *muticus* and it is not that species. It was collected with a shotgun while basking on the bank of a small, mud-bottom stream.

REFERENCES

- BLANCHARD, FRANK N. 1921—A revision of the king snakes: genus *Lampropeltis*. Bull. U. S. Nat. Mus. 114:260, 78 figs.
- BURT, CHARLES E. 1933—Some distributional and ecological records of Kansas reptiles. Trans. Kans. Acad. Sci. 36:186-208.
- 1935—Further records of the ecology and distribution of amphibians and reptiles in the Middle West. Amer. Midl. Nat. 16(3):311-336.
- DAUGHERTY, ANITA E. 1942—A record of *Graptemys pseudogeographica versa*. Copeia 1942(1):51.
- GLOYD, HOWARD K. 1940—The rattlesnakes, genera *Sistrurus* and *Crotalus*. Chicago Acad., Spec. Publ. 4: 1-266, 10 figs., 22 maps, 31 pls.
- GLOYD, HOWARD K. AND ROGER CONANT. 1934—The taxonomic status, range, and natural history of Schott's racer. Occ. Pap. Mus. Zool. Univ. Mich. 287:1-17, 3 pls.
- KOSTER, WILLIAM J. 1940—The first record of the snake, *Hypsiglena*, from New Mexico. Herpetologica 2(2):30.
- ORTENBURGER, A. I. AND BERYL FREEMAN. 1930—Notes on some reptiles and amphibians from western Oklahoma. Publ. Univ. Okla. 2: Biol. Survey no. 4: 175-188.
- POPE, CLIFFORD H. 1939—Turtles of the United States and Canada. Alfred A. Knopf, New York. xviii + 343 pp., 99 illus.
- SCHMIDT, KARL PATTERSON AND D. DWIGHT DAVIS. 1941—Field book of snakes of the United States and Canada. G. P. Putnam's Sons, New York. xiii + 365 pp., 103 figs., 34 pls.
- SMITH, HOBART M. 1934—The amphibians of Kansas. Amer. Midl. Nat. 15(4): 377-528, pls. 12-20.
- 1939—Notes on Mexican Reptiles and Amphibians. Zool. Ser. Field Mus. Nat. Hist. 24:15-35, 2 figs.
- SMITH, HOBART M. AND ARTHUR B. LEONARD. 1934—Distributional records of reptiles and amphibians in Oklahoma. Amer. Midl. Nat. 15(2):190-196.
- STEJNEGER, LEONHARD AND THOMAS BARBOUR. 1943—A check list of North American amphibians and reptiles. Fifth Ed. Bull. Mus. Comp. Zool. 93:xix + 260.
- TAYLOR, EDWARD H. 1929a—A revised checklist of the snakes of Kansas. Univ. Kans. Sci. Bull. 19(5):53-62.
- 1929b—List of reptiles and batrachians of Morton County, Kansas, reporting species new to the state fauna. Univ. Kans. Sci. Bull. 19(6):63-65.
- TRAPIDO, HAROLD. 1941—A new species of *Natrix* from Texas. Amer. Midl. Nat. 25(3):673-680, 5 figs.
- WOODBURY, ANGUS M. AND DIXON M. WOODBURY. 1942—Studies of the rat snake, *Elaphe laete*, with description of a new subspecies. Proc. Biol. Soc. Wash. 55: 133-142, 2 figs.
- WRIGHT, ANNA ALLEN AND ALBERT HAZEN WRIGHT. 1942—Handbook of frogs and toads. Comstock Publishing Co., Inc., Ithaca. xi + 286 pp., 7 figs., 88 pls.
- NATURAL HISTORY MUSEUM,
STANFORD UNIVERSITY, CALIF.

¹ See Smith, 1939, p. 19, for use of *Platypeltis*.

Observations on the Life Cycle of the Common Newt in Western North Carolina

Claude S. Chadwick

There are several published accounts of the life cycle of the common newt of Eastern North America, *Triturus viridescens*. Most notable among these are papers by Gage (1891), Pope (1924), and Bishop (1941). It is the consensus of opinion among these investigators that, while there may be variations in some localities, there are three well-defined stages in the life cycle of *Triturus*, namely (1) a larval water stage, of at least one summer in duration; (2) a terrestrial stage, lasting two to three or four years; and (3) an adult, water stage which probably extends until death. The color of the terrestrial stage is bright red as compared with the olive green of the water stages. Larvae, hatching from eggs laid in the spring, transform into the terrestrial stage in late August or September and migrate to land. After a sojourn of two to four years on land they migrate back to water, developing on the way, or after they get into water, the familiar characters of the adult.

Variations from this typical cycle in the Woods Hole region and on Long Island have been reported by Noble, (1926) and (1929). He states that in these areas the terrestrial stage is skipped entirely, the newts spending their entire lives in water. Bishop (1941) presents evidence that Noble's observations in the Long Island area were faulty and that some of his conclusions are incorrect. Though large, un-metamorphosed forms are often to be seen and may not leave water, there is definitely a terrestrial stage in this locality.

Another variation is reported by Brimley (1921) who states that in the vicinity of Raleigh, N. C., "the newts do not stay in water during the summer but, losing the dermal fin on the tail, leave the water sometime in the spring and do not enter it again until about November." Pope (1924), possibly basing his conclusion on Brimley's observation, makes the statement that "in the south the terrestrial stage is a seasonal phase, all of the newts leaving the water in the spring and returning in the fall." Brimley (1939) reaffirms the peculiar situation observed by him earlier in Wake County but says "in our mountains it (*Triturus viridescens*) seems to have a normal life history."

Incidental to some experimental work on this species the writer has made a study of *Triturus* in and around Highlands, North Carolina, over a period of several years. It is thought that the data accumulating from this work might be of interest for three reasons: First, the area where the observations were made—embracing the corporate limits of the township of Highlands—has an average elevation of 4000 feet. The annual rainfall is around 90 inches and, while the winter temperature may fall well below zero, the summer temperature never climbs above 87° F. Does the high altitude of the area alter the life

cycle as compared with other areas? Second, the data will show that Pope's conclusion regarding *Triturus* "in the south" does not hold, and thirdly, it will lend substance to Brimley's later statement that in the mountains of North Carolina *Triturus viridescens* seems to have a normal life history. These observations relate primarily to the habitat, sizes of the various stages, and the breeding season.

1. *Habitat*.—Adults are to be found in the numerous ponds and lakes of the area at all times during the summer. Collections, particularly in Lake Ravenel and Harbison's pond, have been made repeatedly by the writer in each month from April to September. In spite of earnest efforts to find them, such as turning up stones, raking away leaves and searching under decaying logs, only an occasional greenish form was seen on land. The texture of the skin and the narrowness of the tail indicated that these rarities were not adults that had left water, but rather were terrestrial stages undergoing transformation into adults. The red stages (efts), on the other hand, are rarely seen in water but may be found readily along the trails and road cuts winding up and around Bearpen, Satulah, Shortoff and other mountains in the area. The summit of Bearpen was the best collecting ground. Here, several hundred feet above the nearest standing water, eft stages ranging from 40 to 97 mm. in length were found in abundance. Even a casual observer in this area is bound to be struck by the sharpness of the distinction between the water stages and the land stages as regards habitat and color.

2. *Measurements*.—(a) *Adults*. One hundred seventy-seven adults collected at random in Ravenel Lake and Harbison's pond ranged from 80 to 108 mm. in length, with a mean of 91.74 mm., a standard deviation of 5.21 and a probable error of the mean of 0.264. Among these the sex of 108 was determined by dissection. Eighty-seven males ranged from 81 to 108 mm. in length, with a mean of $92.1 \pm .357$ and a standard deviation of 4.95. Twenty-one females showed a range from 81 to 99 mm., a mean of $91.1 \pm .661$ and a standard deviation of 4.49. Except for the females, which are considerably larger in Highlands, these measurements conform closely to measurements of 178 specimens collected by Bishop in May 1928 from a pond near East Nassau, N. Y.

Trunk length and tail length of 176 adults were compared statistically. The trunk length, taken from the anterior tip of the snout to the posterior angle of the vent showed a range of 40 to 51 mm., a mean of $45.11 \pm .134$ and a standard deviation of 2.66. Tail lengths ranged from 32 to 62 mm. with a mean of $47.2 \pm .207$ and a standard deviation of 4.07. The tail length is thus shown to be on the whole 2.4% greater than the trunk length, but is very much more variable. Here again the data are in essential agreement with those of Bishop on specimens taken in Rensselaer county, N. Y.

(b) *Efts*. Three hundred eft stages, collected at random during the months of June and July in 1937, 1938, and 1939, were carefully measured, the measurements including the overall length, the trunk length and the tail length. Because the eft stages varied so greatly in size, because of different ages, and because

large efters are so much more easily found than small ones, statistical constants for the group are of little value. The smallest eft was 39 mm. in length, the largest 98 mm. All were the typical brilliant red color so characteristic of the eft. To gain a better insight as to their ages a frequency distribution of overall lengths was prepared in the form of a histogram. This histogram showed four modes, one at 50 mm., another at 59, a third at 70, and a fourth at 83 mm., as follows:

	Group I	Group II	Group III	Group IV
Size range	39 to 55 mm	56 to 63 mm	64 to 74 mm	75 to 98 mm
Mode	50 mm	59 mm	70 mm	83 mm

Following the reasoning of Bishop (1941) these four modes may each represent years of age. If they do, then here is a pronounced difference between the Highlands and the New York *Triturus*. The Highlands eft spends a year longer on land and reaches a size averaging 10 mm. greater. These large efters extensively overlap in size the adult water stages, having a range of 75 to 98 mm. as compared with 80 to 108 mm. for the adults. The largest efters are much larger than the mean of the water stage adults.

It is an interesting fact that the tail length of the terrestrial stages is 3.4% less than the trunk length, while in the adults the tail is 2.4% greater than the trunk. This difference indicates that when the terrestrial stages migrate back to water the tail increases not only in breadth, by the addition of a dorsal and ventral fin, but also in length, in becoming the chief organ of propulsion while swimming.

(c) *Larvae*. Not a great deal of attention was paid to larvae, however, an even dozen collected on August 1, 1939, ranged from 30 to 37 mm. in length with an average of 34.5. None were observed undergoing transformation at this time. These measurements agree fairly well with those of Bishop on a greater number collected at East Nassau in August 1927.

3. *Breeding season*.—Egg laying begins in April. Amplexus was observed April 20th, 1938, and several females dissected at this time had eggs already in the oviducts. Egg laying continues into July. One female dissected on July 7th, although the ovaries were spent, had mature eggs in the oviducts. Egg laying thus extends over a period of at least ten weeks. This is about the same as that described by Bishop for the area around Albany, N. Y.

In connection with the breeding season there is this interesting fact. I have found that in random collections of adults from the several ponds and lakes of the Highlands area during June and July, males always outnumber females anywhere from 2 to 1 to 5 to 1. Bishop has described the same thing: among 178 specimens collected by him from a pond near East Nassau, N. Y., in May 1928, only 23 were females; also at Syosset, Long Island, a collection yielded nearly twice as many males as females. One would think from these facts that the sex ratio is not 1 to 1, or that the females hover near the places where they have laid eggs and do not come to the shores where they may be easily caught. An abnormality in the sex ratio is probably not to be suspected for among 100 efters collected at random and the sex determined, 65 were females

and only 35 were males, just the converse of the situation among randomly collected adults. The explanation may be that the females in natural waters do show an hitherto unsuspected broodiness which makes them less likely to be caught, while in the terrestrial stage a greater feeding activity exposes them to the collector.

Migration of maturing land stages back to water occurs in the fall, usually in a wet period following a dry spell, and conforms in all particulars to the vivid description by Stein (1938) for an area in the vicinity of Sunderland, Mass.

REFERENCES

- BISHOP, S. C. 1941—The salamanders of New York. N. Y. State Mus. Bull. 324: 54-82.
- BRIMLEY, C. S. 1921—The life history of the American newt. *Copeia* 1921(94):31-32.
- 1939—The amphibians and reptiles of North Carolina. *Carolina Tips*. 2(3):10.
- GAGE, S. H. 1891—Life-history of the vermilion-spotted newt (*Diemyctylus viridescens* Raf.). *Amer. Nat.* 25(300):1084-1110.
- NOBLE, G. K. 1926—The Long Island newt: A contribution to the life history of *Triturus viridescens*. *Amer. Mus. Nov.* 228:1-11.
- 1929—Further observations on the life-history of the newt, *Triturus viridescens*. *Amer. Mus. Nov.* 348:1-22.
- POPE, P. H. 1924—The life history of the common water newt (*Nolophthalmus viridescens*) together with observations of the sense of smell. *Ann. Carnegie Mus.* 15:305-362.
- STEIN, KATHRYN F. 1938—Migration of *Triturus viridescens*. *Copeia* 1938(2):86-88.

DEPARTMENT OF BIOLOGY,
VANDERBILT UNIVERSITY,
NASHVILLE, TENNESSEE
AND

HIGHLANDS BIOLOGICAL LABORATORY,
HIGHLANDS, NORTH CAROLINA.

Notes on Amphibians and Reptiles from Wisconsin

Richard A. Edgren, Jr.

During the past several years I have seized various opportunities to study and collect amphibians and reptiles in the state of Wisconsin. Specimens were taken while on an auto trip in the summer of 1941; while employed as nature counselor at Camp MacLean, Racine County, and near Ashland, Ashland County, while stationed there by the Army Signal Corps, in the summer of 1943. Specimens have been preserved in my personal collection and in the Chicago Academy of Sciences. The nomenclature of the *Check List* is followed.

Racine County specimens are of special interest as P. R. Hoy (Hoy, 1883) did most of his collecting in the eastern part of the county; and his work has led subsequent authors to accept certain records from Racine that are definitely erroneous. It appears evident that Mr. Hoy brought his personal collection from Ohio with him to Racine; and these Ohio specimens found their way into the United States National Museum after Mr. Hoy's death, with no data except "Racine." I have included notes on specimens taken in and around Racine, Racine County, by Prof. Baird during his stay there in 1853. This list was kindly furnished by Dr. Doris M. Cochran of the U. S. National Museum.

Camp MacLean is a Chicago Y.M.C.A. camp situated between Browns' and Rockland Lakes, 1½ miles East of Burlington, Racine County, Wisconsin.

I am indebted to my parents for the auto trip in 1941, and to members of the Camp MacLean staff for aid in collecting, and especially to Henry Oberheim, III, Larry Ericson, Gerald L. Janousek, Ralph Maynard, R. W. Gawne, and Sidney Eddelstein. Sincere gratitude is extended to Mr. Karl P. Schmidt of the Chicago Natural History Museum, for aid in the preparation of this paper.

Necturus maculosus maculosus (Rafinesque).—The National Museum has a specimen of *Necturus* taken by Prof. Baird from the Root River near Racine, Racine County. It must be referred to *maculosus maculosus* on the basis of locality, but Racine County specimens may be found to approach *maculosus strictus* Bishop.

Triturus viridescens louisianensis (Wolterstorff).—Taken by Baird near Racine.

Ambystoma jeffersonianum (Green).—Four specimens from debris at the bottom of a drop window of the lodge basement at Camp MacLean; and four from under logs in a wooded area about 4 miles east of Ashland.

Ambystoma tigrinum tigrinum (Green).—Tiger salamanders were common in the Camp MacLean area during the summer of 1942; many were taken from the drop windows of the lodge, others from various camp buildings, one was

found under a rock in a large cistern, another under a piece of tar paper, and one under a log in the center of a pond that was drying up, in which larvae abounded. Many eggs were found in the larger ponds in the spring of 1943, and freshly hatched larvae were seen. The eggs began hatching the 30th of April.

A tiny *Ambystoma*, believed to be this species, was taken under a carpet of moss near a drying pond containing larvae. This specimen was described by Bishop as, "the smallest transformed *Ambystoma* I have seen." Its measurements are, total length, 40.6 mm.; length of tail, 16.2 mm.; length of head, 6.0 mm.; width of head, 4.9 mm.; length of hind leg, 6.1 mm.; length of fore leg, 5.9 mm.; and costal grooves, 12.

Plethodon cinereus cinereus (Green).—Eleven specimens of the red-backed salamander from rotting fallen logs near Pelican Lake, Oneida County. Though the day was cold the salamanders seemed as active as usual, scurrying for cover as soon as they were uncovered.

Bufo americanus americanus (Holbrook).—The common toad was found near Pelican Lake, Oneida County; 2 miles south of Wautoma, Waushara County; 1½ miles east of Burlington, Racine County; near Bass Lake, 10 miles east of Antigo, Langlade County; and throughout Ashland County. Breeding of this form had just begun when I arrived in Ashland, May 29th, 1943.

I have made special attempts to find the Fowler's toad in Wisconsin, but without success. It has been recorded from the Apostle Islands in Lake Superior. Mr. Karl P. Schmidt has examined the specimen and informs me that it is unquestionably an *americanus*.

Acris gyrrillus crepitans Baird.—Collected 2 miles south of Wautoma, Waushara County; and observed near Ashland. Taken near Camp MacLean in 1942, and more abundant in the spring of 1943 when the species was common in ponds connected to Rockland Lake. None were found in ponds away from the Lake.

Pseudacris nigrita triseriata (Wied).—At Camp MacLean during the last week in April, 1943, these frogs were just completing mating, and only a few were found singing in the ponds. In contrast with *Acris* no *Pseudacris* were taken in ponds connected to Rockland Lake. All my specimens are from isolated ponds. The breeding season was a full month later at Ashland, almost 300 miles north. Two specimens were taken near Ashland in the bed of a stream late in September.

Hyla versicolor versicolor (Le Conte).—Seven specimens were found sunning themselves on rocks in the bed of a small stream near Ashland. A single specimen was taken near the top of Rib Hill, near Wausau, Marathon County.

Rana catesbeiana Shaw.—One specimen taken at Camp MacLean, and Prof. Baird captured one near Racine.

Rana clamitans Latreille.—Green frogs were taken in Camp Lake, Kenosha

County; at Little Norway, Dane County; Camp MacLean; and the species was heard singing in a slough near Ashland.

Rana palustris Le Conte.—Taken near Racine by Baird.

Rana pipiens brachycephala (Cope).—Taken in Ashland, Kenosha, and Racine Counties. Leopard frogs were singing and laying eggs during the last week of April at Camp MacLean.

Rana sylvatica cantabrigensis Baird.—Many seen and some specimens taken in Ashland County; one specimen seen in Bayfield County about 8 miles south of Ashland. Eggs were found in ponds at Camp MacLean in April of 1943. The t/b ratio of the single male taken at Ashland is .53; in five females it varies from .54 to .57, mean .55; and in four juveniles from .50 to .53, mean .51.

Opheodrys vernalis vernalis (Harlan).—Baird took three specimens at Racine.

Pituophis sayi sayi (Schlegel).—Several specimens were seen DOR on Rib Hill, Marathon County.

Lampropeltis triangulum triangulum (Lacépède).—Baird took a milk snake near Racine.

Natrix septemvittata (Say).—The National Museum has a specimen taken by Baird near Racine.

Natrix sipedon sipedon (Linnaeus).—Taken by Baird near Racine, and I observed a specimen in Silver Lake, 2 miles south of Wautoma, Waushara County, several years ago.

Storeria dekayi (Holbrook).—Several specimens were taken at Camp MacLean. A gravid female was dissected July 15, 1942, and found to contain 24 developing embryos.

Storeria occipitomaculata (Storer).—One specimen taken and several more observed near Bass Lake, 10 miles east of Antigo, Langlade County.

Thamnophis butleri (Cope).—Butler's garter snakes were fairly common in the area about Camp MacLean. Davis (1932) discusses the presence of this snake in Wisconsin and records specimens from Dodge, Waukesha, Milwaukee, and Racine Counties.

Thamnophis radix (Baird and Girard).—One specimen from near Camp MacLean, and another from Camp Lake, Kenosha County.

Thamnophis sauritus proximus (Say).—Baird took a specimen near Racine.

Thamnophis sirtalis sirtalis (Linnaeus).—The common garter snake is quite common throughout Wisconsin. I have specimens from 2 miles south of Wautoma, Waushara County; Camp MacLean; and Camp Lake, Kenosha County.

Crotalis horridus horridus (Linnaeus).—Four skins taken from Sauk County specimens.

Sternotherus odoratus (Latreille).—Musk Turtles were quite common in Rockland and Browns' Lakes near Camp MacLean, and I have taken specimens from Silver Lake, 2 miles south of Wautoma, Waushara County. A nesting rendezvous of these turtles was found at Rockland Lake (Edgren, 1942). The eggs found began hatching on September 4, 1942, and continued almost until the first of October. Four newly hatched young picked at random, measured from 20 mm. to 21.5 mm. in length of shell, and from 14.4 mm. to 16.3 mm. in width. Pope (1939) and Risley (1933) do not mention the fact that the musk turtle is, to some extent, nocturnal. Although often found during the day they are much more common foraging late in the evening, or at night.

Chelydra serpentina (Linnaeus).—A single specimen from Rockland Lake, Racine County.

Clemmys insculpta (Le Conte).—I took two specimens from a slough off the White River, a small, swiftly flowing small-mouth bass stream (about 8 miles south of Ashland) in Bayfield County.

Emys blandingii (Holbrook).—One from Camp MacLean.

Chrysemys bellii bellii (Gray).—Common in Rockland and Browns' Lakes, Racine County.

Amyda spinifera spinifera (Le Sueur).—Mr. Ralph Maynard presented me with a specimen from Eagle Lake, Racine County.

REFERENCES

- DAVIS, D. DWIGHT. 1932—Occurrence of *Thamnophis butleri* Cope in Wisconsin. Copeia no. 3, 113-118, Figs. 1-3.
- EDGREN, RICHARD A., JR. 1942—A nesting rendezvous of the musk turtle. Chicago Naturalist 5(3):63.
- HOY, P. R. 1883—Catalogue of the cold-blooded vertebrates of Wisconsin. Geol. Wisconsin 1:422-426.
- POPE, CLIFFORD H. 1939—Turtles of the United States and Canada. Knopf. pp. xviii-343, illus.
- RISLEY, PAUL L. 1933—Observations on the natural history of the common musk turtle, *Sternotherus odoratus* (Latreille). Papers Mich. Acad. Sci. Arts Lett. 17: 685-711.
- STEJNEGER, LEONARD AND THOMAS BARBOUR. 1943—A Check List of North American Amphibians and Reptiles. Bull. Mus. Comp. Zool., 43(1):xix-260.
- 4722 MANOR AVE.,
CHICAGO, ILLINOIS.

Food Habits and Molting of the Common Tree Frog

Harvey L. Sweetman

Among various species of amphibians kept in a terrarium over a period of years, both for entertainment and observation of habits and activities are some tree frogs, *Hyla versicolor* (Le Conte). Some of these were reared from tadpoles and others were captured after attaining maturity. Either captured or reared frogs did well in captivity, at least for five years.

The cage used in the early observation was a gallon salad dressing jar with cheese cloth over the top held in place with rubber bands. Moistened sand was placed on the bottom of the cage to a depth of half an inch. A limb from a tree about an inch in diameter was placed diagonally from the bottom on one side to the top on the opposite side of the jar. The tree frogs usually came to rest on this limb. Later a glass cage 16 x 10 x 12 inches, with a glass cover was used. This contained a small pan of water at one end with soil over the remaining portion of the bottom to the level of the top rim of the water pan. Low spreading plants growing over the soil served no useful purpose, other than appearance. The frogs did well in either cage, but always seemed restless for a few days when placed in a new environment.

Room temperature was satisfactory for the frogs as they were active and fed readily at 18° to 24° C. At 15° they were somewhat sluggish, but such exposures were of short duration. They remained active throughout the year at room temperature, showing no need of a hibernation period. Moist conditions are essential. If the humidity became too low the tree frogs burrowed into the sand or soil to reduce evaporation from their bodies. The degree to which they covered themselves served as an indicator of atmospheric moisture. They occasionally burrowed to escape annoyance from flies. Generally they preferred to burrow rather than enter water to maintain moisture requirements, although at molting time they may show the opposite response.

Some discrimination between species of insects and spiders is shown by this species. This varied with the degree of hunger. Tree frogs from one-third grown to maturity were fond of crickets, *Gryllus* and *Nemobius*, but almost entirely refused the cave crickets, *Ceuthophilus*. Most flies are readily accepted. There is a marked correlation between size and acceptance. A newly transformed individual, about one-half inch long, will eat only minute insects, such as small gnats and midges. A month later in development these minute insects seemed to be ignored and forms the size of fruit flies are preferred. Two to four months after transformation they transfer their interest to larger food, such as house flies. About this time small crickets were readily accepted, although difficulty in swallowing such large insects was evident. Half to full grown tree frogs did not feed on insects much smaller than house flies, even after several days starvation. Moths and butterflies in general are not on the

preferred food list. Caterpillars are readily accepted. Large larvae of the tiger swallow-tail butterfly, *Papilio glaucus*, var. *turnus* L., were repeatedly eaten by an adult tree frog. At no time did the frog exhibit any response either through odor, taste, or by contact, to indicate that it was aware of the yellow Y-shaped repugnatorial glands (osmeteria) or the vapor from them, although the sickening odor became intense in the cage. When offered attractive food that is much larger than usual, a hungry frog may hesitate before hopping onto the victim. At such times excitement is indicated by twitching of the toes on one or more feet. Similar twitching of the toes has been observed when the proffered food makes slight or infrequent motions.

The tree frogs exhibit some fear of certain insects that show great activity and are large in comparison to the usual food. If a large insect escaped after a struggle, the frogs were reluctant to attempt recapture. Avoidance of stinging insects seemed to develop from experience. In food netted from vegetation, all forms except large wasps were offered. On one occasion a frog was apparently stung by a wasp from a sweep net collection. It immediately captured it, but then fell over backwards, dragged the wasp from its mouth and continued to scrape at its mouth with its fore feet for some minutes, and avoided all insects as large as the wasp for several days.

Providing food in winter becomes a problem. Fruit, house, and other flies were reared for food. Fruit flies are easy to rear at any season, but once the frogs gain some size and have eaten the larger flies, they refuse the smaller ones. Offering fruit flies for as long as a week was not sufficient to stimulate the frogs to return to feeding on these small insects.

A period of starvation of about 10 days was serious for a rapidly growing individual; a definite spinal deformity developed as a result. As soon as food was offered further bone development appeared to be normal. Although this individual lived for nearly four years beyond this starvation period its demise appeared to be a direct result of the spinal deformity. More mature individuals, except for losing weight apparently, were little the worse for short starvation periods.

Molting has been observed a number of times. The molting process is influenced by moisture conditions. If the humidity is considerably reduced, the tree frogs burrow into the soil and partially cover themselves. At such times they can be induced to molt by moistening the soil so that water is left standing; they settle in the water for a few minutes and begin to shed their skins.

It is well known that tree frogs eat their molted skins. Noble (1931, p. 40) states that swallowing of the skin begins before molting is completed and that movements of the throat and fore limbs assist in peeling off the old skin, that of the limbs being turned inside out in the process. My observations indicate that molting and swallowing of the skin are simultaneous processes in *Hyla versicolor*. The first evidence of molting is a general twisting of the body, perhaps most easily described as resembling a youngster removing a tight slip-over sweater without turning it inside out. Swallowing of the loosened skin accompanies these movements. The body is somewhat distended with air. The

twisting may continue for some minutes with only slight pauses and appears to be rather strenuous. The twisting alternately shortens and lengthens each side of the body and with swallowing the skin is gradually pulled forward. At intervals the mouth is opened in conjunction with swallowing giving the appearance of gasping for air. Close observation revealed the loosened skin being pulled forward along the body and legs and entering the mouth at its corners. Apparently the skin from the limbs is pulled directly into the mouth and not turned inside out as suggested by Noble.¹ The tongue was not observed to assist in starting or pulling the skin into the mouth. Intermittent periods of strenuous twisting may be followed by intervals of comparative quiet. From time to time the hind feet may be rubbed over the back apparently to assist in loosening or pushing the skin forward. Occasionally the front feet may be rubbed over the head and face in such a way as to help in pushing the skin toward the mouth. The leg action varies considerably in different individuals when molting, apparently depending upon the ease with which the skin is loosened and pulled into the mouth. Portions of the loosened skin may be seen stretched between a leg and the body, but always being pulled forward to the mouth. The moist, slimy skin must remain intact if it is to be completely eaten. At times fragments of the shed skin were observed hanging on the legs or on the glass after a molt. Molting requires from 45 minutes to about two hours for completion. Successive molts have been observed 10 days apart, but this may not be the normal interval. The skin is usually much brighter after molting.

The frogs often fed immediately before and after molting and feeding has been observed while molting following a short period of starvation.

MASSACHUSETTS STATE COLLEGE,
AMHERST, MASS.

¹ Noble, G. K. 1931. The biology of the amphibia. (Citation on page 40). McGraw-Hill, N. Y.

The Root System of Aspen¹

Maurice W. Day

The quaking aspen (*Populus tremuloides* Michx.) is widely distributed. In the Lake States region it occupies a larger area than any other tree species. Because it occupies such a large area and because of the difficult silvicultural problem which it presents, this species demands careful investigation. The present study was initiated with the objective of adding to the knowledge of the silvics of the species.

Many authors in discussing this species have made reference to its root system but few authors have considered the root system in detail. Baker¹ found the typical root system in the central Rocky Mountain region to be shallow with many root suckers. He presented two figures to illustrate root systems that he had excavated and studied.

This is a study of the root system of aspen conducted at the Dunbar Forest Experiment Station near Sault Ste. Marie, Michigan. The root systems of a large number of aspen seedlings, sapling and small trees were excavated in part or entirely. The trees were growing on several different sites which are briefly described.

The area wherein tree number 1 was located is a level sandy area. The soil is a fine sand with a profile development indicating that it belongs in the Rubicon series. The tree discussed was located on the edge of an aspen-grassland ecotone. The ground cover in the open area consists of june grass with a scattering of dewberry, bracken fern, reindeer moss, and aspen suckers. Within the aspen stand the bracken fern is much more dense, the grass is more sparse, and the dewberry is absent. A scattering stand of white spruce (*Picea glauca* [Moench] Voss) up to two feet in height is also present. The site index for aspen is between 55 and 60.

The area supports a few scattered white pine (*Pinus strobus* L.) about sixty years of age. These white pine all have fire scars and from ring counts it was determined that the fire had occurred about thirty-one years ago. Age determinations of a number of aspen in the vicinity gave ages of thirty years or less in all cases. It can be assumed, therefore, that this aspen stand became established following this fire either from seedlings or suckers. The small number of thirty year old trees indicates that the initial stand was sparse and that the stand was probably filled in with suckers.

Tree number two was one studied on a site created eight years ago by the dumping of clay dredged from the bottom of the St. Mary's River. The soil is a grey clay without any evidence of profile development. This clay has a dis-

¹ Contribution from the Forestry Section, Michigan State College, East Lansing, Mich. Authorized for publication by the Director as Journal Article No. 633 (n.s.) of the Michigan Agricultural Experiment Station.

tinct cubical structure which was readily evident when it was subjected to water under pressure.

The ground cover consists largely of grasses and annual weeds with a few scattered aspen and willows. The ground surface is not completely occupied by vegetation.

The seedlings examined were located within the forest nursery area. The soil here is a fine sand which has been enriched by the addition of peat. The aspen seedlings were located in sparsely stocked seed beds and along rows of transplants. The favorable moisture conditions and lack of competition from weeds or grasses provided suitable conditions for their development.

The roots of most of the aspen studied were exposed by the dry method. This method has been used by most of the workers who have studied tree root systems. The root crown of the tree selected is first uncovered by careful hand digging, thereby revealing the main lateral roots. The roots selected for study are then carefully dug out and mapped as the work progresses. Pits are dug alongside of the vertically descending roots so that the soil may be removed from them.

Tree number two was excavated completely by the hydraulic method, which has been described by Stoeckler and Kluender, (4). It consists of the use of water under pressure from a nozzle to effect the removal of the soil from the roots. By the use of this method, it was possible in this case to expose the entire root system.

In general, aspen has a widespread lateral system of roots that gradually merge into the roots of suckers which have arisen from the parent system. While taproots are usually absent, the sinkers or vertical roots descending from the laterals may descend to considerable depth under some conditions. Practically the entire lateral root system is contained in the top foot of soil and in many cases nearly all of the lateral roots are in the top six inches of soil.

A distinguishing feature of the aspen root system is the presence of many root suckers which make it difficult to distinguish individual root systems except in the case of small seedlings. A number of factors evidently influence the production of suckers. Kittredge and Gevorkiantz (2) and others have noted the large numbers of suckers which result following cutting or fire. The trees in this study were all found to have produced some suckers, but usually only where overhead shade was lacking. In some cases, however, the suckers were widely spaced and in other cases closely grouped for no apparent reason. They usually arise from a lateral root which is within four inches or less of the surface of the ground. There was a marked thickening of the root at the point of origin of each sucker but only on the side away from the parent tree. This indicates that the translocation of food material produced in the leaves of the sucker was towards the growing tip of the root and not towards the parent tree.

The vertical root development consisted of sinker roots descending from the lateral roots at varying distances from the parent tree. Sinker roots descended in old root channels in almost all cases and their course and depth seemed to depend largely upon the location of the former roots. Their development pro-

vides secure anchorage and enables the tree to utilize subsoil moisture during periods when the surface soil is dry.

Under natural forest conditions it is usually impossible to locate any aspen seedlings, moist unoccupied soil being essential for their establishment (5). Those examined in the present study had become established in the forest nursery, where they found conditions suitable for germination and growth, and were characterized by a fibrous branching lateral root system. Definite taproots were present in only a few cases, and the maximum depth reached by the roots during the first season's growth was usually less than six inches. During the first year the seedlings attained a height of from six inches to two feet. The lateral roots produced during this period do not usually exceed twelve to sixteen inches in length.

By the second year the aspen root system has become more woody and less fibrous and has extended itself widely. A few cases were noted where suckers were produced during the second year. The length of the laterals may reach six feet or more during the second year while the stem height will usually be from two to four feet. Seedling height growth is comparable, but usually not equal to that of suckers. Seedling height and root growth exceeds that of all

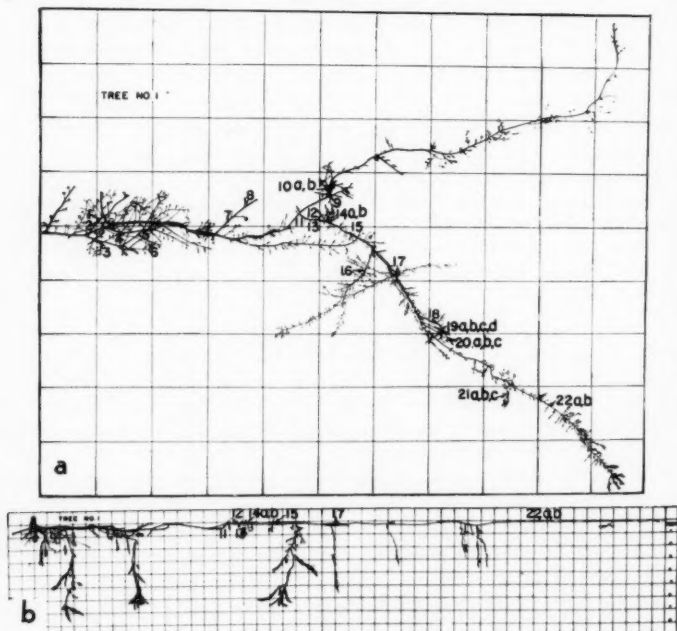


Fig. 1a. Plan of main lateral of tree no. 1. Scale: 1 division = 4 ft. b. Transsect view of main lateral root of tree no. 1. Scale: 1 division = 1 foot.

aspen's common associates except pin cherry (*Prunus pennsylvanica* L.).

Figure 1 illustrates the course of the main lateral root of an eighteen year old aspen growing on Rubicon sand. This tree was a sucker and the root from which it arose can be seen at the left side of the figure. Only the main lateral root was excavated and when it was found to divide into two equal branches, both were followed out. Only a few of the smaller side branch roots were followed out in detail. This tree was located on the edge of a group of aspen of similar age and size and the lateral root extended into an open grassy area which was being invaded by aspen suckers, a number of which were found to be a part of the lateral root studied.

Counts of the annual rings in the basal cross section of the various suckers and in the root cross sections taken at intervals along the root indicate the approximate rate of elongation of the root and the date of suckering. Figure 4 shows in graphic form the rate of growth of these roots. A comparison of this graph with Table 1, indicating the age of the various suckers, shows that the appearance of suckers was often long delayed.

TABLE 1.—Age of Suckers shown in Fig. 1.

Number of Sucker	Age Years	Distance from tree—feet	Height—feet
1	.....	Does not arise from main stem	1.0
2	dead	Does not arise from main stem	....
3	13	Does not arise from main stem	6.0
4	dead	Does not arise from main stem	....
5	dead	Does not arise from main stem	....
6	.....	Does not arise from main stem	2.1
7	dead	9.2	....
8	7	11.4	8.5
9	4	16.6	8.1
10 a	5	17.1	8.5
10 b	4	17.1	4.2
11	dead	15.1	....
12	3	16.2	4.5
13	2	16.5	2.5
14 a	4	16.9	8.0
14 b	4	16.9	7.3
15	4	18.9	8.0
16	8	21.6	6.5
17	8	23.7	8.9
18	dead	28.7	....
19 a	5	29.4	4.0
19 b	6	29.4	4.6
19 c	6	29.4	5.0
19 d	5	29.4	7.0
20 a	6	30.2	7.0
20 b	3	30.2	5.2
20 c	5	30.2	2.3
21 a	4	36.3	2.1
21 b	5	36.3	5.5
21 c	5	36.3	4.5
22 a	2	39.3	1.1
22 b	2	39.3	1.0

It may be noted from figures 1a and 1b that the horizontal root system was wide spread and quite heavily branched, and that the horizontal roots were very close to the surface. Rarely did the primary horizontal roots lie below six inches from the surface; however, there were a number of secondary branch roots, or sinkers, that extended to considerable depths. Noteworthy was the fact that all of these roots were growing in old root channels. These root channels were

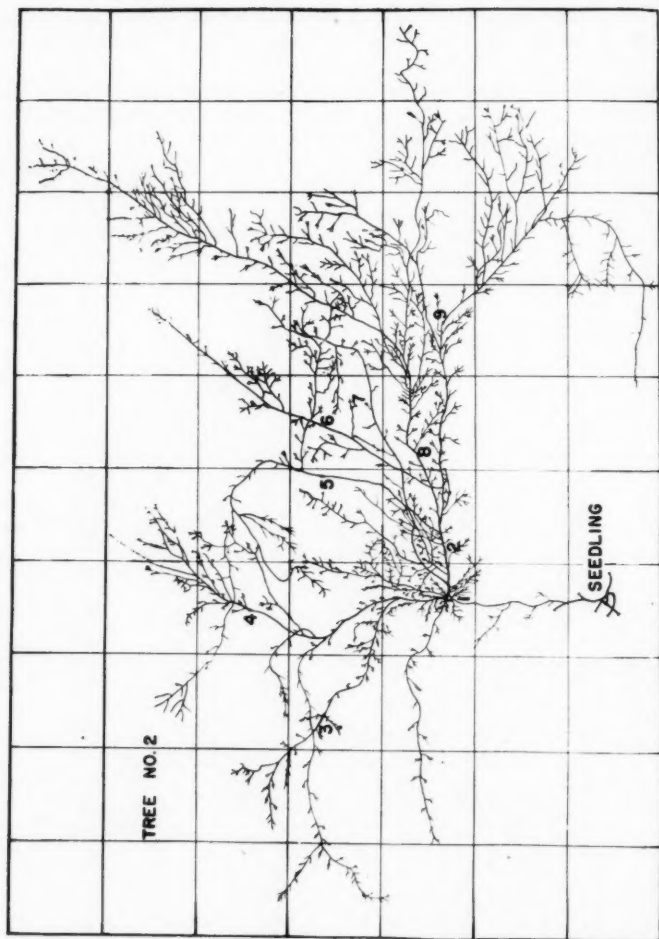


Fig. 2. Plan of root system of tree no. 2. Scale: 1 division = 4 feet.

completely filled by a dense mass of roots which were enclosed within the bark of the old root in many cases. At their lower extremity the sinker roots were spread out in dense fan shaped mats of roots. Figure 3 shows a typical root mass taken from a depth of six feet below the surface. The greatest depth reached was slightly more than seven and one-half feet. In podsolic soils with dense hardpan the presence or absence of such old root channels may greatly influence the development of the root system.

Tree number 2 was chosen with the thought of being able to trace the development of a root system from seed. The tree chosen was found to be a sprout from a nearby seedling. The location of the seedling with its attaching lateral together with the complete root system of tree number two is shown in Figure 2. This tree (Sprout number 1 on Figure 2) was six feet in height. It was growing in an open area which was sparsely covered with weeds and grasses. A number of what appeared to be aspen seedlings were scattered about but upon excavation they were found to be suckers from the same root system. This root system was completely excavated and furnished some interesting evidence regarding the development of a root system with limited vegetative competition. A willow clump located to the right of the seedling on the figure was the only other shrub or tree present. Its presence probably accounts for the lack of aspen root development in that sector.

The lateral root system was found to resemble that of tree number 1 in that it remained close to the surface. In some cases, however, the roots descended to nearly one foot and a few secondary branch roots descended at sharp angles to



Fig. 3. Development of sinker root at 6 feet below surface.

a depth of slightly over two feet. These were the deepest roots encountered and it may be that these roots would have in time developed into sinker roots similar to those of tree number 1.

The roots of aspen are, in general, cylindrical with but little taper except close to the suckers. The aggregate volume was considerable. As a measure of the amount of roots produced, the volume of the roots of sprout number 1 and its eight other younger sprouts was contrasted with the volume of the above ground portions. The volume of the roots totaled 780 cc. and the volume of the tops 412 cc. as determined by the water displacement method.

The silviculture of aspen is largely concerned with the conversion of aspen stands to other species (3); the aggressive rooting habits of this species make conversion difficult. While the evidence indicates that aspen invades sodded areas on light soils only slowly, the root system once established is capable of withstanding drought and even hot surface fires. On areas of limited competition the initial stand of seedlings is rapidly augmented by suckers. In later years it will usually be found that what appears to be even-aged stands originating from seedlings are instead largely suckers which originated from seedling root systems within a few years after the seedlings were established. Seedlings will be produced only under certain favorable conditions, but it is evident that invasion by means of suckers is rapid provided sufficient light and moisture are present.

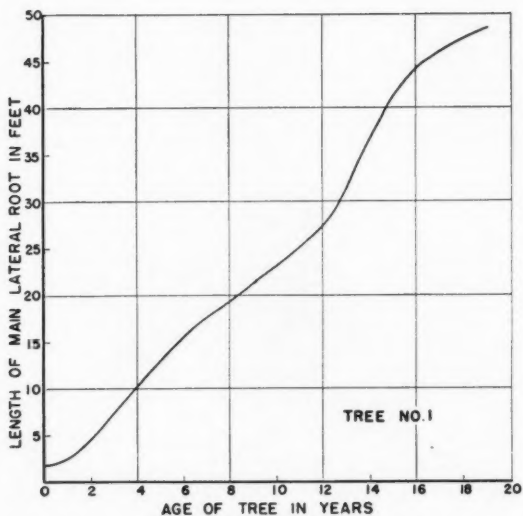


Fig. 4. Growth of main lateral root.

SUMMARY

The examination of the root systems of aspen seedlings, saplings and small trees revealed that:

1. The root system of aspen seedlings on moist sandy soil was usually strongly lateral with fine fibrous roots. The length of the laterals was usually less than sixteen inches.

2. By the second year the main lateral roots had extended themselves from four to six feet and suckers had appeared.

3. On podsolic soils with a dense hardpan the development of sinker roots was correlated with the presence of old roots and root channels in the soil.

4. An aspen tree eighteen years of age and twenty-five feet in height had a main lateral root forty-seven feet in length with branch sinker roots reaching a vertical depth of seven and one-half feet. This lateral root had eight suckers directly on it and many more on the branch roots.

5. An aspen seedling eight years of age had a sucker six years of age and six feet high which had an extensive root system with the longest lateral thirty feet in length. There were eight suckers on this root system. The volume of the root system was 780 cc., whereas, the volume of the tops was 412 cc.

6. It is essential to recognize the rooting and suckering ability of aspen when subjecting it to silvicultural treatment.

REFERENCES

1. BAKER, FREDERICK S. 1925—Aspen in the central Rocky Mountain region. U. S. Dept. of Agr. Bul. 1921, 47 pp. illus.
2. KITTREDGE, JOSEPH, JR. AND S. R. GEVORKIANTZ. 1929—Forest possibilities of aspen lands in the Lake States; Univ. of Minn., Agr. Exp. Sta. Tech. Bul. 60, 84 pp. illus.
3. SHIRLEY, HARDY L. 1941—Restoring conifers to aspen lands in the Lake States. U. S. Dept. of Agr. tech. Bul. 763, 36 pp. illus.
4. STOECKELER, J. H., AND W. A. KLUENDER. 1938—The hydraulic method of excavating the root system of plants. Ecology 19:355-369 Illus.
5. MOSS, E. H. 1938—Longevity of seed and establishment of seedlings in species of *Populus*. Bot. Gaz. 99:529-542.

DUNBAR FOREST EXPERIMENT STATION,
SAULT STE. MARIE, MICH.

Notes on *Navarretia Abramsii* of the Polemoniaceae

Helen K. Sharsmith

For many years *Navarretia Abramsii* Elmer (Bot. Gaz. 41:314. 1906), a species endemic to the central Coast Ranges of California, was so little known as to be considered a "lost" species. Knowledge of it was based on three early collections from the type locality in the Santa Cruz Mountains of the South Coast Ranges, and an additional early collection, of questionable authenticity, from Lake County of the North Coast Ranges. Recently, however, it was discovered by the writer to be abundant in the Mount Hamilton Range of the South Coast Ranges, and in addition it was recollected in Lake County of the North Coast Ranges. On the basis of these further collections, particularly the abundant material from the Mount Hamilton Range, there is now available a greatly extended knowledge of the species' geographic range and habitat, and morphological data have been accumulated which are critical to its generic status.

The geographic range of *Navarretia Abramsii*, as known at present, is summarized in the following: rocky soil of chaparral areas; in Santa Clara County, San Mateo County, and Stanislaus County (Santa Cruz Mountains and Mount Hamilton Range) of the South Coast Ranges, and in Lake County of the North Coast Ranges, California.

The following citations include all collections known for the species: South Coast Ranges, Santa Cruz Mountains, Santa Clara County. Black Mountain, Elmer 4586, type (S), isotype (UC!); Pendleton 1473 (S,UC), Dudley in 1903 (S), topotypes. Santa Cruz Mountains, San Mateo County. Emerald Lake, Rose 37658 (CA). Mount Hamilton Range, Santa Clara County. Santa Isabella Creek, H. K. Sharsmith 1160 (UC); Seeboy Ridge, H. K. Sharsmith 3738 (UC); between Arroyo Bayo and San Antonio Valley, H. K. Sharsmith 3307 (UC); Arroyo Mocho, H. K. Sharsmith 951 (UC); between Arroyo Mocho and Colorado Creek, Mason 8313 (UC), head of Colorado Creek, H. K. Sharsmith 3184 (UC). Mount Hamilton Range, Stanislaus County. Arroyo del Puerto, H. K. Sharsmith 1816 (UC). North Coast Ranges. Lake County. Coldstream, Brandegee in 1884 (UC); between Lower Lake and Knoxville Mine, Mason in 1935 (UC); between Burns Valley and Borax Lake, Hoover 3554 (UC).

When the species was recently discovered to be abundant in the Mount Hamilton Range, the idea arose that the Black Mountain of the Mount Hamilton Range was the type locality rather than the Black Mountain of the Santa Cruz Mountains. Both are in Santa Clara County, and Elmer had collected in both areas. The species has not been found in the Santa Cruz Mountains since 1910. In response to a letter, however, Elmer replied, May 22, 1936, as follows: "I distinctly remember having collected it [*N. Abramsii*] along a border of chaparral . . . in the Santa Cruz Mountains. . . . As I remember it was rare, and I found it only once." The Pendleton topotype sheet confirms this; its label reads "summit of Black Mountain, Santa Clara County, elevation 2787, June 18, 1910," which according to United States Geologic Survey topographic maps,

is the summit elevation of Black Mountain in the Santa Cruz Mountains. Black Mountain in the Mount Hamilton Range is 3850 feet high.

Throughout its range, *Navarretia Abramsii* is an almost constant associate of *Adenostoma fasciculatum*. Elmer, in the type description (*op. cit.*), says, "It . . . is chiefly confined to dry gravelly soil immediately bordering thickets of the California chamiso (*Adenostoma fasciculatum* H. & A.)." In the Mount Hamilton Range, *Navarretia Abramsii* is almost entirely confined to the areas of hard chaparral where *Adenostoma fasciculatum* is dominant. The nearly complete restriction of *Navarretia Abramsii* to chaparral is ecologically noteworthy, for the herbaceous undercover in normal, undisturbed chaparral is very limited. Cooper (Broad sclerophyll vegetation of California, Carn. Publ. Wash. 319:1-124. 1922) states that only a few herbaceous species can be considered as peculiar to the chaparral, and his list of these is composed entirely of perennials. *Navarretia Abramsii*, however, definitely qualifies as an herbaceous species, in this case an annual, peculiar to the chaparral, and, even more specifically, to the chaparral of which *Adenostoma fasciculatum* is the dominant species.

It is difficult to decide why Elmer originally placed *Navarretia Abramsii* in *Navarretia* rather than the closely related *Hugelia*, for in the type he describes the anthers as sagittate (Elmer, *op. cit.*), a feature considered to be diagnostic of *Hugelia*. Also, *N. Abramsii* has bracts and calyces imbedded in white wool, another diagnostic feature of *Hugelia*. In *Navarretia* the bracts and calyces are glabrous to varyingly pubescent, but not lanate. In addition, the general habit of the species at once suggests *Hugelia* rather than *Navarretia*. Perhaps Elmer considered *Navarretia* and *Hugelia* to be congeneric, but he made no mention of this.

Whatever Elmer's basis for ascribing *Navarretia Abramsii* to *Navarretia*, later workers have made its status in this genus appear less anomalous by interpreting the anthers as oval rather than sagittate (Brand, Pflanzenreich IV, 250: 152. 160. 1907; Jepson, Man. Fl. Pl. Calif. 788. 1925; Craig, Bull. Torr. Bot. Club 61: 385. 422. 1934). Brand unites *Hugelia* with *Navarretia*, but includes *N. Abramsii* in section *Eunavarretia* of subgenus *Echinocephala*. Jepson separates *Hugelia* and *Navarretia*, and places *N. Abramsii* in the latter genus. Craig, who treats *Hugelia* as a subgenus of *Gilia* and considers *Navarretia* as a separate genus, points out that *N. Abramsii* is more closely related in general aspect to *Hugelia filifolia* (Nutt.) Jepson than to any species of *Navarretia*, but he does not consider *N. Abramsii* to be a *Hugelia*. Craig describes one variety of *Hugelia filifolia* as having anthers which are frequently oval at the base, and he believes that *H. filifolia* and *Navarretia Abramsii* form a connecting link between the two genera.

Thus it appears that anther shape is the determining factor in the generic disposition of *Navarretia Abramsii*, and that workers have disagreed as to the actual shape of the anthers in this species. From the abundant collections now available from the Mount Hamilton Range, however, it is possible to settle this problem. When herbarium specimens are examined microscopically, the very small anthers (0.3-0.4 mm. long) appear to be oval at the base. If these anthers

are placed in water they become turgid in a few seconds, and then they are seen to be sagittate at the base as described for *Hugelia*. If investigation stopped at this point, alliance of *N. Abramsii* with *Hugelia* would be implied, but when the anthers of various species of *Navarretia* and *Hugelia* are similarly examined, no essential difference in anther shape can be found in any of the species of either genus. In both genera the anthers are versatile and the two anther lobes are free below the point of attachment of the filaments, producing a "sagittate" base. In the species with anthers as small as those of *Navarretia Abramsii* and certain varieties of *Hugelia filifolia*, the tissues contract after the pollen is shed, and the anthers then appear oval. Many *Hugelia* species, however, have anthers up to 2-3 mm. long, and in these the sagittate base is evident in the dried specimens. The sagittate shape may even be increased after dehiscence in these larger anthers, for the lower half of each anther lobe curls outward as it dries. The erroneous impression that *Hugelia* has sagittate anthers and *Navarretia* has oval anthers is due to the fact that the anthers are often larger in *Hugelia* than in *Navarretia*. A few *Hugelia* species have anthers as small as the smallest anthers in *Navarretia*, and then the dried anthers appear oval as in *Navarretia*.

These findings eliminate the major technical basis upon which *Navarretia* and *Hugelia* are maintained as separate genera. There remains only the lanate or non-lanate nature of the bracts and calyces to distinguish the two genera. Even this distinction might be questioned, for in certain species of *Navarretia* (e.g., *N. intertexta*), the bracts and calyces are abundantly covered with a pubescence of white scales which simulates the lanate pubescence on the bracts and calyces of *Hugelia* species.

Detailed study of all species of these two genera is necessary before their generic relationships and the position of *Navarretia Abramsii* can be fully clarified. It should be noted that the above results were based entirely upon a comparative study of anthers which had shed their pollen. Possibly some difference in anther shape could be substantiated if fresh, unopened anthers were compared. When the general habit is considered along with the difference in bracts and calyces, the two genera appear to represent distinct and natural units. Until further study determines the presence or absence of other technical distinctions between *Navarretia* and *Hugelia*, however, it is advisable to utilize the conservative treatment of Brand, and consider both as congeneric under *Navarretia*, but instead of including *N. Abramsii* in the subgenus *Echinocephala*, section *Eunavarretia*, it more properly belongs in the subgenus *Hugelia*.

Notes and Discussion

Bibliographical Miscellany—V.

Sara Allen Plummer Lemmon and her "Ferns of the Pacific Coast"

Joseph Ewan

At the conclusion of the interesting and now rare little brochure (1) written by John Gill Lemmon (1832-1908) entitled "Ferns of the Pacific Coast including Arizona" (15 pp. 1882) and subtitled "A full conspectus of the tribes and genera with a classified list of the species giving principal points of distribution and localities of growth," Lemmon included an "announcement" to the effect that Mrs. J. G. Lemmon contemplates publishing a "Manual of Pacific Ferns," as soon as the necessary illustrations can be prepared. This work will give complete descriptions, both technical and popular, and, it is believed, will supply a long-felt want on this coast" (p. 15). Thirty years later *Who's Who in America* (7:1248, 1912) records that Sara Allen Lemmon is the author of "Western Ferns" but no date is given there for this title, presumably still a contemplated work. Jepson, who has written a warm but critical biography of John Gill Lemmon and, incidentally, of his wife, in the *Dictionary of American Biography* (11:162-163, 1933), does not mention the existence of such a work by Mrs. Lemmon. Subsequent search at the Library of the New York Botanical Garden failed to reveal any work by Sara Lemmon. Maxon in his summary of fern literature for North America north of Mexico (*Proc. U. S. Nat. Mus.* 23:621-623, 1901), which is unusually complete, does not list any publication by Sara Lemmon up to that time. Nor is there such an entry in Carl Christensen's *Catalogus Literaturae of his Index Filicum* (1906) or of the three *Supplementa* to that nomenclator (1913, 1917, 1934).

During a visit to the Library of the Missouri Botanical Garden in December, 1937, I discovered what I judge to be the only eventual "publication" on this subject by Mrs. Lemmon. It is an article entitled "The ferns of the Pacific Coast," with a parenthetical subtitle "(Read before the Academy of Sciences by Mrs. S. A. P. Lemmon)" which appeared in the *Pacific Rural Press* under date of March 26, 1881.

Because this article, which appeared in an obscure weekly journal, contains notes on Pacific Coast ferns deserving of more permanent record the more important portions of the four and one-half column article are reproduced here. The article has fifteen topical divisions, beyond the three introductory paragraphs, as follows: Geographical Range; Floral divisions; Peculiarities of distribution; the Origin of ferns; the Life of a fern; Fern sporangia; Cell wall of the spore; Another method of fern growth; Some peculiarities of the frond; Fern literature of America; New ferns of the Pacific Coast; *Notholaena Lemmoni*, Eaton; *Notholaena nivea*, Gillies; *Aspidium mohrioides*, Bory; Little known ferns; Uses, benefits, etc., of ferns. Nine of these fifteen topical divisions are reproduced here *verbatim*, with commentary by the present author on certain statements, as well as some emendations and corrections. A photostatic copy of the entire article is preserved in my botanical library.

The Ferns of the Pacific Coast. (2)

(Read before the Academy of Sciences by Mrs. S. A. P. Lemmon)

The ferns of the Pacific coast, found growing nowhere else in the whole world, except as exported or cultivated, represent 20 species and four well-marked varieties. The number found on the Pacific coast, as well as elsewhere—i.e., the cosmopolites—are 42 species and 14 distinctly-marked varieties; adding these to the exclusively Pacific coast ferns, we have in all 62 species and 17 varieties.

In all North America, north of the Mexican boundary, there have been discovered, up to date, 151 (3) species and 24 (4) varieties. From this, it will be observed, the Pacific coast claims more than one-third of the entire number. With such a large proportion of this interesting and most beautiful division of the vegetable kingdom represented, it seems fitting, as we have attempted, to segregate from all directions, and put the material into compact and available form. This has been done with painstaking and no little research, compiling from the latest authorities; the newly-discovered ferns being described from personal observation, aided by the microscope, upon the living plants and the dried specimens of the herbarium.

Let us touch briefly, as the hour permits, upon the geographical range of ferns; their brief American literature, and, lastly, in a general way, tell something about the latest discovered ferns, together with the uses of ferns in general.

GEOGRAPHICAL RANGE

Ferns generally love heat, shade, moisture and stillness; hence, are most abundant in the islands of the tropics, but they are distributed over all quarters of the globe, always in much smaller ratio than the flowering plants.

The whole number of species known and described up to date is about 3,000 (5). Four hundred and sixty species are found in the single island of Java; the small island of Ceylon has 214 species; the West Indies, in round numbers has 400. On the mainland, Brazil has 381; the Isthmus of Panama nearly 120; while tropical America reaches the large number of nearly 1,000. Contrast with these regions North America, north of Mexico, with its 151 species; all Europe, 67; and the Arctic zone, only 26 species.

The ratio of ferns to flowering plants may be readily seen by citing two or three examples:

Tropical America has 1 fern to 35 flowering plants.

New Guinea has 1 fern to 4 flowering plants.

United States (east of Mississippi) has 1 fern to 46 flowering plants.

FLORAL DIVISIONS

North America presents four natural floral divisions—the Atlantic slope, the Valley of the Mississippi, the Rocky mountain region and the Pacific slope. (6) When we speak of the Pacific coast, in this paper, let it be understood that we mean a *naturally* distinct division, bounded on the south by Mexico, on the east by a line through the mid-valley regions, lying between the Rocky mountains and the Sierra Nevada range, extending northwestward to Alaska. This gives a wide range of temperature; from the hot tropical and forcing, through the milder temperate, to the dwarfing cold of the Arctic regions. All these conditions are, also produced, of course, by difference of altitude, from the humid coast to the ever-snow-clad peaks of the region.

Special climatic conditions are the result of peculiar trends of coast and mountains, producing special flora. For example, the large number of plants, including the great sequoias and Santa Lucia, or Bracted fir, (7) found only in limited localities of this region.

Ferns are always associated with ideas of shade, coolness, shelter and protection, mostly nestling around rocks or clinging to trees, filling up the shady interstices. There is, however, one exception to this law, which is very notable. A so-called variety of *Pellaea Wrightiana* is found on Mount San Bernardino, growing out in open sunny slopes, like a *Delphinium*, or larkspur, the *Salvia*, etc., and for this reason, combined with others, based upon contracted fronds, ashen hue, extreme rigidity, etc., we believe it to be distinct. (8)

PECULIARITIES OF DISTRIBUTION

Sometimes identical species appear in the most widely-separated regions. An illustration may be given of one of our own ferns, *Aspidium mohrioides*, known as the "Falkland Islands Shield fern," first discovered on the Falkland Islands, in 1824, by

the botanists of Duperry's voyage, later at Patagonia and in the mountains of Chile; all the while limited to the southern part of South America and its adjacent islands. Now, away up in northern California, near Mount Shasta, 6,000 mile from its nearest known habitat, Mr. Lemmon discovered, in 1879, this beautiful fern, which was at first supposed by Prof. Eaton to be a distinct species. It excited such attention that a council of distinguished pteridologists assembled, and, after due examination, felt obliged to consider it identical with this Falkland island fern; but, as it is a magnificent fern, new to North America, and found near the matchless Shasta, we give it the popular name, in the catalogues, of "New Shasta fern."

All but one species of ferns are terrestrial. This one (*Ceratopteris thalictroides*) (10) is aquatic, and is found in the everglades of Florida; the sterile frond floating on the water.

All but a few species are perennial, and nearly all of these, particularly the tree-ferns, are evergreen.

FERN LITERATURE OF AMERICA

Not till after our country had dated its century did any systematic work upon ferns, scientific or popular, appear from our American press. Much has been done abroad in reference to our ferns, by Sir W. J. Hooker; and later his son, Sir Joseph D. Hooker, with several others, has continued the work in bringing out general reports and descriptions of ferns and the rest of *Vascular cryptogams*. Since that time, in the year 1878, Prof. J. Robinson has issued a neat little work, "Ferns in Their Homes and Ours," full of interest and a valuable help to those who wish to cultivate these most graceful plants. Then followed an octave volume on the "Ferns of Kentucky," illustrated with etchings from nature, by Mr. Williamson. Following close upon these came a check list of ferns, on a single sheet by Mr. Wm. Edwards of Natick, Mass., intended as a convenient medium of exchange.

In 1879 Mr. George E. Davenport published under the auspices of the Massachusetts Horticultural Society of Boston, a valuable and most instructive catalogue, or it might be called commentary, of some 40 pages, relating to the Davenport herbarium of North American ferns. In 1880 "A Systematic Fern-list of the Known Ferns of the United States of America, with the Geographical Range of the Species, and the Recognized Authorities for Nomenclature," was issued by Prof. D. C. Eaton, as an accompaniment to his large, exhaustive and finely illustrated work on "Ferns of North America." This comes to us in two large volumes of over 600 pages—not mere picture books of ferns, but they stand in the first rank, as a work of close, scientific research, a very present help to a close study of the ferns of our Pacific coast. The results of these studies it becomes a real pleasure to report.

NEW FERNS OF THE PACIFIC COAST

The new ferns, or those but lately discovered and described, are ten in number:

<i>Notholaena Newberryi</i> , Eaton.	<i>Cheilanthes viscida</i> , Davenport.
<i>Notholaena Grayi</i> , Davenport.	<i>Cheilanthes Cooperae</i> , Eaton.
<i>Notholaena Lemmoni</i> , Eaton.	<i>Cheilanthes Clevelandii</i> , Eaton.
<i>Notholaena nivea</i> , Desveraux. (11)	<i>Aspidium Nevadaense</i> , Eaton. (12)
<i>Cheilanthes Wrightii</i> , Hooker.	<i>Aspidium mohrioides</i> , Bory. (9)

Three of these, *Notholaena Grayi*, *Notholaena Lemmoni* and *Notholaena nivea*, were only detected last season, in Arizona, and hence are not described and illustrated in Eaton's "Ferns of North America." These, with the peculiar and hardly less interesting *Aspidium mohrioides*, will be described in a general way in conclusion with the uses of ferns.

The *Notholaena Grayi*, *Lemmoni* and *nivea* are all small, delicate and fragile, white-powdered beneath, growing in nearly the same locality—Mt. Santa Catarina (11) and Mt. Graham, southeast Arizona. The two first are plume-like, the latter pyramidal in outline.

The *Notholaena Grayi*, Davenport, is a beautiful little fern, growing from four to

six inches in height, is broad-lance shaped in outline, but simulating a plume-tip. The stalks are few in number, and rise from a knobby or nodose root-stalk, growing in clumps on the grassy slopes of the foothills, under the shade of rocks. It was found many years ago by Mr. Schott, in Sonora, Mexico, but owing to the meager, fragmentary specimens, it being fragile and difficult to preserve, it was supposed to be portions of some other fern, and so was passed by, till again collected within the boundary of North America, by Wm. M. Curtis, in February or March, 1880, in southeast Arizona, the exact locality not reported, and by Mr. Lemmoni [sic] in April of the same year, in Sanoita valley, Patagonia mountains of southern Arizona. Larger and finer plants were collected in August on the foothills of Mt. Graham, near Camp Grant, southeast Arizona. Mr. Davenport describes it as a lovely fern and quite different from any known species, and so cannot be compared. Under the microscope the white powder separates into distinctly stalked, gland-like bodies, with enlarged, conical, flat or inverted heads, like a miniature host of fungi, with their variously shaped cups. The little brown scales that, with the powder, give it such rich color, under a power of 200 diameters, become like long, tapering tubes, which contain the brown coloring matter, which, collected at the base or at intervals throughout the scale, gives it the appearance of being jointed. It is a beautiful object for the microscope. Mr. Davenport concludes: "This species is one of the most elegant yet discovered, and I take pleasure in dedicating it to one preeminent in American botanical science—Dr. Asa Gray."

Notholaena Lemmoni, Eaton

(Lemmon's silvery-plume *Notholaena*): During the same exploring expedition Mr. Lemmon fortunately detected a beautiful, silvery, plume-like *Notholaena*, appearing unlike any he had ever before seen. With eagerness he secured all the specimens possible, together with a few live roots from among the clefts of granite rocks. Its known habitat is in two ravines on the southern side of the Santa Catarina mountains, at an elevation of about 6,000 ft., and about eight miles from Fort Lowell. These fragile but carefully prepared specimens were sent on to Prof. Eaton, and he at once replied: "Your No. 15 appears to be a new *Notholaena*." In the next issue of the Bulletin of the Torrey Botanical Club, June, 1880, he publishes a description of the fern under the above name. The close botanical description is also in its classified place with our Pacific coast ferns.

Notholaena nivea, Gillies. (11)

(The snowy *Notholaena*.) In the following month, the same party, while at Tombstone mines searching along the granite comb above, regardless of the millions of rich quartz beneath his feet, discovered on this granitic eminence, at about 6,000 feet elevation, a delicate, snowy *Notholaena*, which, upon close inspection, proved to be the *Notholaena nivea*, its appearance true to its name. It was first discovered in Mexico, and as far south as Peru, but this is its first recognized welcome to our own land.

It is a very pretty and interesting fern, with prim, black, wiry and polished stalks supporting its pyramidal fronds, that thus stand rather proudly, beckoning, as it were, to the prospector, and hinting, by its silvered pinnules, flecked with golden fruit, that untold treasures of silver and gold are hidden in the silence of the rocky bed beneath. This species is also technically described in its proper order of analysis of the ferns of the Pacific coast.

Aspidium Mohrioides, Bory. (9)

(The new Shasta shield fern) We come finally to speak of the most interesting discovery in ferns that has occurred for many years—the magnificent evergreen, full-fruited *Aspidium*, before spoken of as being found only at two widely removed stations on the globe, the southern part of South America and here, 6,000 miles distant in northern California, near Mt. Shasta.

This fern slightly resembles full-fronded specimens of *Aspidium aculeatum* variety *scopulinum*, but is of a brighter, richer green, with pinnatifid or many-winged pinna; its fruit abundant, and so crowded upon the back of the frond that the very large covering over the spor [sic] cases or fruit are lapped or imbricated [sic], like saucers on a

sideboard; an appearance that is preserved in many of the herbarium specimens to a remarkable degree.

On the 8th of July, in '78, Mr. Lemmon discovered this fern near the headwaters of the Sacramento river, on the south side of Mt. Eddy, 20 miles west of Mt. Shasta (13). It grows around granite boulders, in moist places, accompanied by the varieties of *Aspidium aculeatum*, the *Scopulinum* or "little brush fern." This association and close resemblance of the two ferns has no doubt caused the escape from detection heretofore.

This circumstance of location also opens the door to a wide field of inquiry, as to why these closely resembling yet structurally different forms should be found in juxtaposition. Which is the pioneer possessor of the soil? Which is the usurper, simulating the livery of the rightful heir and encroaching upon his domains? Or is there some subtle power in the elements of proximity of the lofty Shasta, that modifies and blends these gentle, passive ferns into almost like forms.

LITTLE KNOWN FERNS

There are several little known ferns, found at long intervals of time by some especially sharp-eyed explorer—perhaps seen only once along the Mexican boundary. In some instances the specimens are meager, being but a single frond, or only a few segments of a frond. Of these, Prof. Eaton entertains the hope that some one will be so fortunate as to find some of the ten at least, or as he adds, re-discover the *Notholaena tenera*, (14) the tender little cloakless wanderer; *Cheilanthes microphylla*, the small-leaf lip-fern; *Cheilanthes leucopoda*, the white-stalk lip fern; *Pellaea pulchella*, (15) the most beautiful little cliff-brake; *Pellaea aspera*, (16) the rough cliff-brake; *Adiantum tricholepis*, the silky-leaf maiden-hair; *Adiantum tenerum*, the tender-leaf maiden-hair; and *Asplenium septentrionale*, the northern spleenwort—all the above named being reported from the southern boundary. In the other direction, among the islands of Alaska, the *Cheilanthes argentea*, of Hooker, the silvery lip-fern, is supposed to be found, as it is abundant on the northern coast of Asia.

Notes of Commentary

1. This "First Edition"—the only edition ever published—was priced, according to the title page, at thirty-five cents a single copy or \$3.50 per dozen; printed by Bacon & Co., Printers, San Francisco.

2. The title was closely approached by Lorenzo Gordon Yates when he published "Ferns of the Pacific Coasts" in Pop. Sci. News 36: 244-246. 1902, to which I have previously referred (Am. Fern Jour. 24:7, 9. 1934). Yates' paper, similarly, was "read at the session of the Pacific States Floral Congress, held in San Francisco, Calif., in 1901."

3. Maurice Broun lists 335 native species for the same geographic area (Index N. Am. Ferns 169. 1938).

4. Broun, *ibid.*, gives 222 formae and 109 varieties.

5. Filicineae (inc. Ophioglossales, Marattiales, Filicales) include 8000 spp. (A. J. Eames in 1936).

6. Cf. "geographical divisions" of John H. Redfield, Bull. Torr. Bot. Club 6:1-7. 1875, where a sounder world wide basis is given the subject and 6 divisions are recognized, viz., 1. cosmopolitan, 2. boreal, 3. Appalachian, 4. Pacific, 5. New Mexican and 6. Tropical.

7. Santa Lucia Fir (*Abies venusta* (Dougl.) Koch).

8. The present author has entertained the same view, on very closely parallel evidence (Jour. Wash. Acad. Sci. 25: 363-370. 1935), supporting the specific status of *Pellaea compacta* (Davenp.) Maxon.

9. Cf. H. St. John (Madrono 6: 223-227, 1942) on type locality of *Polystichum Lemmoni* Underw., interpreted as a distinct Pacific Coast species by Underwood, Maxon and St. John. Fernald considers it *P. mohrioides* var. *Lemmoni* (Underw.) Fern., Rhodora 26:92. 1924.

10. Now known as *C. pteroides* (Hook.) Hieron.

11. Now understood to be *N. limitanea* Maxon, *N. nivea* Desv. being a tropical

American species. Lemmon's "Mt. Santa Catarina," as he also spelled it on his labels of plants from that range, is the Santa Catalina Mts., of Pima County, culminating with an elevation of 9,150 ft.

12. Known at present as *Dryopteris nevadensis* (D. C. Eaton) Underw.

13. The statement of locality—"on the south side of Mt. Eddy, 20 miles west of Mt. Shasta," July 8, 1878,—lends support to St. John's decision to select as lectotype the Mt. Eddy sheet annotated by Underwood in the Herb. of N. Y. Bot. Gard., rather than the alternate sheet arbitrarily selected by Gleason and accepted by Wheeler (Am. Fern Jour. 27:121-126. 1937), originally labelled "near Shasta, California, July, 1879." Though the collection date given by Sara Lemmon is four days prior to any specimen seen by either Wheeler or St. John (and perhaps written by Sara Lemmon from memory), it would be difficult to find more reassuring evidence for a type locality than this: (a) contemporary letters describing Mt. Eddy trip, published by St. John (b) Eaton's citation of Lemmon's locality data, published under "*Aspidium mohrioides*" (1879) (c) Sara Lemmon's clear statement (1881) quoted here as to the source of J. G. Lemmon's material. (d) one additional point may be suggested: the label of a J. G. Lemmon coll. of *P. scopulinum* (Ewan Herb.) reads "Mt. Eddy, n. Sierras, Cal., near Shasta, 6000 ft.—found with mohrioides." Lemmon may have used the phrase "near Shasta" as one of general geographic orientation due to the unfamiliarity of the Mt. Eddy region among botanists. The presence of a semicolon before that phrase in J. G. Lemmon's listing (1882, 12) weakens this last suggestion, however. There is the possibility that the semicolon is there a *lapsus typographicus*, the locality cited representing but a single station rather than two stations as would otherwise be the case.

14. Now understood to be *N. Jonesii* Maxon, a species distinct from *N. tenera* Gillies.

15. Now understood to be referable to *P. microphylla* Mett.

16. Now understood to be referable to *Cheilanthes horridula* Maxon.

UNIVERSITY OF COLORADO,
BOULDER, COLORADO.

Record of Alligator Juniper (*Juniperus pachyphloea* Torr.) on the Jornada Experimental Range, New Mexico

Arthur F. Halloran and Fred N. Ares

The record of the flora of the Jornada Experimental Range in south-central New Mexico does not include the Alligator Juniper (*J. pachyphloea* Torr.). (See Little and Campbell, 1943, *Amer. Midland Natur.*, vol. 30, no. 3, p. 656.) Visits just south of the area on Black Mountain at the southern end of the San Andres Range and to Rhodes Pass, approximately 40 miles to the north, in the northern part of the San Andres Mountains had shown the tree to be a common dominant at suitable locations at approximately 6500 feet elevation. As it was to be expected that the tree might be found between these two areas on the Jornada Experimental Range, careful note was taken on field trips. In November 1943 a single tree was found in Ash Canyon; since then two more trees have been located, one in St. Nicholas Canyon and one near Goldenburg Springs, all on the Jornada Range. A specimen is now in the field herbarium at the headquarters area of the Jornada. Doubtless further search will reveal more specimens of this species scattered among the more common one-seeded junipers (*J. monosperma*) and pinyon pines (*P. edulis*), the only other members of the Pinaceae on the area.

FISH & WILDLIFE SERVICE,
LAS CRUCES, N. M.
AND
U. S. FOREST SERVICE,
LAS CRUCES, NEW MEXICO.

Book Reviews

THE NATURAL FEATURES OF SOUTHERN FLORIDA ESPECIALLY THE VEGETATION, AND THE EVERGLADES. By John H. Davis, Jr. Florida Geological Survey, Geological Bulletin no. 25, 311 pp., 70 text figs., 10 tables. Tallahassee, 1943.

To many naturalists Florida is the most fascinating state of the United States. Those of us who have had the privilege of spending some time there find that its scenic features, its geologic history, its anthropological problems, and the beauty of its multitudinous wild life combine to cast a spell which simply cannot be resisted. Added to the fascination of the rich Coastal Plain flora, which never fails to intrigue the botanist and nature-lover, there is the seductive mystery of a subtropical and, on the Florida Keys, an actual tropical flora. Only one state exceeds it in number of species and that is California with its vastly greater area and altitudinal range. According to Small's classic "Manual of the Southeastern Flora," representing the summation of a very active lifetime of almost continuous work on the flora of that vast region, there are at least 569 endemic species and varieties of flowering plants in Florida, of which 383 are limited to the southern portion of the peninsula. In addition, there are at least 549 subtropical and tropical species and varieties which can be seen wild in no other part of continental United States, most of these being northern outliers of Bahaman, Cuban, and other West Indian species. Several hundred more species are almost confined to Florida, their ranges extending out of the state only into adjacent portions of Georgia or the Gulf Coast region of Alabama, Mississippi, Louisiana, and Texas. A number of species are found in the United States only in southern Florida and a small subtropical portion of southeastern Coastal Plain Texas.

This high percentage of endemism is not limited to the flowering plants, either. Dr. Murrill and others have shown that it holds also for certain groups of cryptogams. That it holds also on zoology is indicated by the names in the following partial list of birds and mammals: Florida cardinal, Florida wren, Florida duck, Florida crane, Florida jay, Florida blue jay, Florida great blue (or Ward's) heron, Florida burrowing owl, Florida barred owl, Florida wild turkey, Florida deer, Florida panther, Florida bobcat, Florida black bear, Florida otter, Florida wolf, Torch Key raccoon, Key Vaca raccoon, etc. Simpson's classic work on the breathtakingly beautiful epiphytic *Liguus* tree-snails of Florida describes numerous apparently endemic subspecies.

Dr. Davis, who is Research Assistant to the Florida Geological Survey, has done an excellent job in presenting his monograph on the natural features of southern Florida, in which he describes and discusses some of the historical and anthropologic-ethnologic aspects, as well as the main topographic, climatic, geologic, and biologic features of the vast region south of the northern borders of Lake Okeechobee. Nor is this his first work on the region. In 1940 he produced a 109-page monograph on the ecology and geologic rôle of mangroves in Florida and in 1942 an 82-page work on the topography, vegetation, and ecology of the Sand Keys. All through his book there are footnotes giving sources of information and adding up to an extensive bibliography. It is to be regretted, however, that a more complete bibliography wasn't included as a supplement and that the author seems to have been unacquainted with the voluminous writings of Dr. Small in the "Journal of the New York Botanical Garden" and elsewhere, where a vast amount of information—not only botanical, but also ecological, zoological, geological, and anthropological—is available. Davis cites some of Dr. Small's manuals and floras, of course, but Small was a geologist as well as a botanist, and a keen observer of all the natural features of the region. This reviewer has not been able to find anywhere in Davis' work any mention of Small's theory of the periodic flooding of the Everglades through the agency of underground streams which have broken through the overlying rock strata in the innumerable "bathtub sink-holes" in the great basin occupied by the Everglades and Big Cypress.

Southern Florida may be divided into ten fairly distinct physiographic regions, each

of which has its own characteristic ecology and flora: (1) the Everglades—Lake Okeechobee Basin, (2) the Eastern Flatlands, (3) the Western Flatlands, (4) the Big Cypress, (5) the Lake Istokpoga—Indian Prairie Basin, (6) the Highlands Ridge or Lake Region, (7) the Atlantic Coast Strip and Miami Rock Ridge, (8) the Southern Coast and Islands, (9) the Southwest Coast and Ten Thousand Islands, and (10) the Florida Keys.

Lake Okeechobee, covering about 725 square miles and including endemic fish, is the second largest freshwater lake wholly within the United States. South of it are the Everglades, occupying 3600 square miles, about 80 percent of which is marshland, with some slough, swamp, and hammock areas. The elevation varies from 17 feet in the north-central region to about 8 feet at the Tamiami Trail and nearly sea-level at the southwestern end of the basin. East and west of the northern part of the Okeechobee and Everglades region are the remains of three marine terraces built up by the Pamlico, Talbot, and Penholoway seas of the glacial stages which occurred during the Pleistocene. These are the two Flatlands regions, the eastern covering 1275, the western 3500 square miles. The elevation here rises to above 42 feet. The Big Cypress "swamp," in which about a third of the native Seminole Indians still live, is an undefined area covering about 1200 square miles west of the 'glades. The Lake Istokpoga—Indian Prairie region covers 250 square miles between the Eastern and Western Flatlands and borders the eastern side of the Highlands Ridge escarpment, the southern tip of which occupies about 145 square miles and varies from slightly over 130 feet to 40 feet in elevation. The Atlantic Coast Strip has the tidal rivers, lagoons, shore ridges, beaches, dunes, and islands typical of coastal areas. The southernmost part of this strip is without a deep sand mantle over the oolitic limestone and is known as the Miami Rock Ridge, in some places 20 feet above sea-level. South of Miami begins an arc of low-lying coast with tidal flats extending a mile or more inland and very few beach strips. On these coastal areas are many huge mangrove swamps and salt- to brackish-water marshes, creeks, ponds, lakes, and nearly landlocked bays. The Southwest Coast is one of the most dissected and least accurately known coastal regions of the world, with thousands upon thousands of mangrove-covered islands. The tidal range, up to 4 feet in some instances, causes tidal inundation of large areas up to ten miles inland and forces salt water far up most of the estuary rivers, bringing marine life, including the rare and sluggish sea-cow or manatee, with it. The Florida Keys form an arc 200 miles long from above Miami to the Dry Tortugas. The northern keys are of coral rock (Key Largo limestone), while the southern ones are of Miami oolite.

It is believed that the last sea to cover southern Florida did so not over 50,000 years ago. During its Penholoway stage only the present Highlands sandhills and adjacent areas above the present 70-foot contour lines were not flooded. After the Pamlico stage the sea probably receded to levels 20 or more feet below the present one. This level was then followed by a slow rise in sea-level, which rise is still continuing at the present time.

The abundance of low moors or marshlands has produced a tremendous deposition of peat. It has been estimated that the state can produce 2 billion short tons of air-dried peat, of which half occurs in the Everglades. The presence of this peat, varying in the 'glades from a few inches to 8 feet in depth, accounts in part for the tremendous damage done by fires in the Everglades and especially in the islands of tropical or subtropical vegetation known as hammocks. Hammock fires have been known to burn continuously for many years until there is actually nothing left but the bare rock substratum.

The author states that there are twenty distinct soil types in the region and the types of vegetation are in many instances so closely related to the soil types that specific soil areas are covered by specific types of vegetation. There are few, if any, other large areas in the Southeastern States where there is such an intimate relation between soil type and vegetation. Twenty-four general types of vegetation are described under the general heads of Pine Forests, Pine and Oak Forests and Scrub, Hammock Forests, Swamp Forests, Marshes, and Prairies. The dominant or co-dominant species as well as species of high constancy are listed for eight major soil types.

Considerable, and in many instances regrettable, changes in plant and animal life and ecology are being created by the lowering of the water-level in the Everglades

through drainage. This drying up of the region is aided and abetted by the rapid transpiration of marsh plants, which often transpire nearly twice as much water as is lost by evaporation from an open water surface. The drying up of the region causes the incidence of fires to increase, accompanied by more serious destruction of peat, hammocks, and wild life. Drainage has also caused a subsidence of land so that about 250,000 acres of land near Lake Okeechobee that used to slope away from now slope towards the lake.

The great variety of wild life in southern Florida is due partly to the overlapping of the south temperate and subtropical climate conditions and partly to local variations in the soils, water-levels, rainfall, and other conditions. One of the most unusual features is the great number of woody plants—trees, shrubs, bushes, woody vines, and semi-woody shrubs. There are over 90 species of large trees and 125 small trees and shrubs. In the open pine forests the low shrubs may cover as much as 50 percent of the area, in many cases crowding out nearly all grass and herbaceous growth. The transition from plants of temperate climate affinities to plants of tropical affinities takes place gradually from north to south in Florida. Fifteen species of palms and 89 of orchids, many of the latter being epiphytic tropical species, are found in the state, while on the Florida Keys—the only part of the state exempt from killing frosts—are found such tropical trees as mahogany, *lignum-vitae*, mastic, wild-tamarind, stoppers, bastic, and gumbolimo.

The author describes 68 distinct types of vegetation in southern Florida, with type locations cited for each. A listing of some of these types will serve to give a fair idea of the intriguing diversity represented: high pine forests, sand soil pine flatwoods, shallow soil and low rocklands pine flatwoods, pine and cabbage-palm hammocks, cabbage-palm hammocks, low hammocks, Miami rock limesink hammocks, coastal hammocks, coral rock jungle hammocks, Lower Florida Keys hammocks, Cape Sable—Madeira Bay hammocks, southern Everglades hammocks, mixed hardwood and cabbage-palm hammocks, royal palm mature hammocks, immature hammocks, mixed swamps, river, slough, and lake-border cypress swamps, cypress-domes and cypress-heads, cypress strands, stumpy or scrub cypress forests, bay galls, pineland bay-heads, marsh tree-islands and swamp-border bay-heads, thicket swamps, custard-apple swamps, pop-ash swamps and ponds, willow swamps, mangrove swamp forest, strand vegetation, sawgrass marshes, flag marshes, aquatic-plant marshes, cattail marshes, spikerush or needle-grass marshes, mixed herb and shrub marshes, fern marshes, bulrush marshes, low shrub marshes, salt-grass marshes, switch- or cord-grass marshes, black-rush marshes, salt flats and salt prairies, potted prairies, marginal prairies, seasonally wet sand-pond prairies, switch-grass prairies, muck and sandy muck prairies, marl wet-prairies, rockland wet-prairies, saw-palmetto prairies, etc.

Of the 9,000,000 acres of land in southern Florida about 52 percent is not forested and 73 percent of the non-forested area is marshland. The Everglades occupy 2½ million acres. Among the most outstanding features of the region are the hammocks. Hammocks are defined as hardwood and palm forests usually dominated by broad-leaved evergreen trees and limited to relatively small areas, growing on high upland to seasonally flooded soils and containing a great variety of south temperate to tropical species. They are often a climax forest developed after a series or succession of other stages of vegetation. They are the treasure-houses to which the naturalist, whether botanist or zoologist, fights his way, confident of high rewards. The subtropical hammocks of the mainland often have as many as 50 species of trees and shrubs forming a dense growth, made almost impenetrable by the tremendous development of climbing vines, ferns, and epiphytes. Although at Key West nearly any tropical plant will grow without protection from frost, the hammocks are not completely tropical forests anywhere on the mainland, for the live-oak, hackberry, mulberry, and red maple range south of Miami. For this reason the mainland hammocks are regarded as subtropical and only the Florida Keys hammocks are truly tropical. One small hammock south of Miami was found to contain 125 species of ferns and flowering plants, of which 82 percent were West Indian. The hammock is a unique botanical feature and one of the most hauntingly beautiful scenic objects of southern Florida, especially when it occurs like an oasis in the vast marshland Everglades or prairies.

Another fascinating feature of the region is the abundance of prehistoric kitchen-middens, burial mounds, and village sites, especially along the coastal dunes, and the remarkable ecology of these spots. Some of the middens measured by Small are of such tremendous proportions that one is staggered when one tries to estimate how long the ancient inhabitants must have lived there in order to assemble so many shells. That these priceless relics of the distant past are ignored and even destroyed by huge power shovels scooping them up by the thousands of truck-loads in road-building operations is an eternal blot on the state! Many of these middens are now covered by hammocks and the species inhabiting them are most characteristic. The Cuban bristlegrass, *Chaetochloa hispida*, is found only on the shell mounds of Marco Island. Two species of century plant, *Agave decipiens* and *A. neglecta*, are endemic to these kitchenmiddens and coastal hammocks. They show no relation to West Indian species of the genus, but are related to a Mexican group. Probably they represent prehistoric introductions from Mexico. If this is so, their Mexican ancestors have since died out or else the Florida plants have evolved rapidly. A wild pepper, *Micropiper leptostachyon*, a milkwort, *Polygala aboriginum*, and a prickly-pear, *Opuntia stricta*, are almost limited to prehistoric village sites and middens, as is also the endemic prickly-apple, *Harrisia aboriginum*. Some West Indian plants, like *Amyris balsamifera*, *Myriopus poliochros*, and *Mentzelia floridana*, which inhabit the coastal hammocks, in the northern part of their range occupy only the middens and ancient burial sites. A Brazilian cactus, *Brasilopuntia brasiliensis*, is practically confined to the middens of the mainland coast and Florida Keys. What are the implications of the almost exclusive presence of these and other species on prehistoric middens? Do they furnish us with clues as to the origin of the people?

The author rightfully deploras the gradual extermination of so many of the wild plants and animals of the region. Although the reviewer cannot find any mention of the paroquets and ivory-billed woodpeckers which used to inhabit the area, Davis does discuss the flamingo, egret, ibis, and heron situation. The official slaughter of the Florida deer and its subsequent replacement by a northern subspecies certainly seems unjustified. In 1930 over 20,000 alligator skins were handled by one west Florida dealer alone—and yet some folks wonder why the alligator is becoming as rare as the crocodile! Only 50 everglade kites are left and only 15 to 20 reddish egrets. Roseate spoonbills, which used to be "common" on both coasts, are now limited to about 120 birds. There is only one rookery of eastern glossy ibis left. The Florida wolf is probably extinct, and the panther, black bear, gray fox, and wild turkey are almost gone. The manatee will be obliterated soon unless sanctuary is provided. Davis rightfully adds his voice to that of naturalists everywhere who are pleading for the speedy establishment of the proposed Everglades National Park. The heroic work of the National Audubon Society in protecting the wild life of the region cannot be praised too highly. "Time is running out on the Everglades, and whatever conservation of the water supply, soils, vegetation, and wildlife is to be carried out should be done quickly. The wildlife, botanical, and scenic values of the Everglades are deteriorating rapidly." Already the vast custard-apple swamps, with the endemic Okeechobee gourd and *Commelina gigas*, are gone into oblivion, being replaced by sugarcane fields.

In short, the monograph is a valuable contribution on a fascinating and little-understood region. The numerous illustrations, many of them aerial views, are splendid, although one could have wished for more. It is unfortunate that the manuscript and proofs were edited so poorly, because typographic and other errors are extremely abundant—errors such as "temperature" for "temperate" (p. 92), the transposition of four species and their common names (p. 100), "dodocandra" for "dodecandra" (p. 96), "Pycnothamnus" for "Pycnothymus" (p. 97), "course" for "coarse" (p. 103), "Pollyrhiza" for "Polyrrhiza" (p. 141), "praires" for "prairies" (p. 146), "cabage" for "cabbage" (p. 148), "of" for "or" (p. 149), "cinerac" for "cinerea" (p. 156), "Kruz" for "Kurz" (p. 159), "Simarauba" for "Simarouba" (p. 169), "Hippicratea" for "Hippocratea" (p. 171), "higer" for "higher" (p. 173), "avocada" for "avocado" (p. 185), "acreas" for "acres" (p. 193), "acquatic" for "aquatic" (pp. 195 & 196), "herbaceaus" for "herbaceous" (p. 195), "capallifolium" for "capillifolium" (p. 263), "Kunthe" for "Kunth" (p. 264), "Polyganum" for "Polygonum" (p. 265), "broken" for "bracken" (p. 267), and "migricans" for "nigricans" (p. 268). On page 200 the

sea-lavender is called "*Mallotonia gnaphloides*" (instead of *Mallotonia gnaphalodes*), while on page 203 it is called *Tournefortia*. On page 194 the sea-blite is called *Suaeda linearis*, while on page 207 the generic name *Dondia* is used. On page 207 the generic name *Monanthochloë* is misspelled "*Monanthochloa*." The name for the sea-grape is in some cases given as "*Coccoloba*" and in other cases as "*Coccolobis*." On page 188 the statement is made that there are only three species of mangrove in the New World. Actually there are six. On page 235 it is stated that "it... seems that the near extinction of the kite is due mainly to discriminate shooting." Obviously, "indiscriminate" is the word intended. There are numerous cases of repeated and misplaced lines of type and many grammatical errors which should have been caught in the editing.

In view of the general excellence of his work to date, for the few criticisms listed above are very minor and inconsequential matters, it is to be sincerely hoped that the author will continue his splendid and valuable investigations in Florida and will publish many more such classic monographs as this.—H. N. MOLDENKE, New York Botanical Garden.

ORGANOGENESIS IN RUBUS. By Charles J. Engard. University of Hawaii Research Publication No. 21. Honolulu, 1944. xvi + 234 pp., 448 figs., 3 table, frontispiece.

"Organogenesis in Rubus" is a book which reflects the increasing trend within recent years to approach the subject of plant morphology from a dynamic standpoint. As a factual contribution, this monograph presents the results of an intensive study of the structure and ontogeny of organs and tissues in four species of *Rubus*, viz., *R. pubescens* Raf., *R. idaeus* (L.) strigosus (Michx.) Maxim. Pom. var. *Cuthbert*, *R. hawaiiensis* A. Gray, and *R. rosaeifolius* Smith. As a contribution to theory, the book stresses "the correlation of form and function, which, with evolutionary change in each, forms the basis of the true philosophy of morphology." The "Introduction," which outlines Dr. Engard's views on the morphology of "the modern plant" is followed by two brief chapters treating, respectively, of the classification and gross morphology of the species investigated, and of the methods employed. Chapters IV-X deal in turn with the stem apex, the foliage leaf, the cataphyll, the ontogeny of the various tissue-systems of the stem, the cell types in the stem, the root, and the ontogeny of the flower. In each of these chapters, the author discusses critically his own observations and conclusions with reference to classical theory and modern interpretation. The concluding chapter of the monograph is entitled "*Organa Sui Generis* or *Organa Homologata*?" Here Dr. Engard develops fully his views on the homology of organs and tissues in the sporophyte. The book is attractively printed on paper of excellent quality and is profusely illustrated by photomicrographs and by line-drawings of excellent quality. An index is included.

A careful study of Dr. Engard's treatise can only awaken admiration for his efforts to integrate and to correlate his own data with the rapidly-accumulating literature in developmental anatomy. Within the limits of this review it is obviously impossible to examine critically all the varied topics and interpretations which are presented. A few examples of important factual contributions in this monograph however deserve consideration. First, in *Rubus*, another example is added to the growing list of angiosperms in which the procambium and protophloem pursue a strictly acropetal development in the shoot as well as in the root. Furthermore, acropetal differentiation of procambium is true of the flower of *Rubus*, a fact which removes one of the supposed histogenetic differences between vegetative leaves and floral organs. Dr. Engard finds no support from his observations for Grégoire's idea that vegetative and floral apices are "irreducible." On the contrary in *Rubus*, there is an ontogenetic transition from the vegetative to the floral apex. Despite the eventual differences between these apices, all appendages in *Rubus*, vegetative and floral, are initiated by periclinal divisions in the subsurface layer of the tunica. With reference to the ontogeny of stem tissues, Dr. Engard has made a valuable observation on the origin of fibers. Confirming the recent work of Esau on *Nicotiana* and *Linum*, the first fibers in *Rubus* arise in the protophloem concomitant with the crushing and obliteration of the sieve-tubes. This leads to the conclusion that in the stem there is no tissue which histologically or functionally corresponds to a so-called "pericycle."

It is regrettable that the many admirable discussions of histological and morphological

topics are marred at several points by an inadequate and in some cases an inaccurate treatment of the literature. Thus, for example, Dr. Engard credits the present reviewer with the conclusion that Hanstein's histogen theory "placed emphasis on individual cells" (p. 8). There is no basis for this erroneous statement either in the original article by Hanstein or in the reviewer's paper. On the contrary, Hanstein held the opinion that the extension and plane of division of individual cells in the shoot apex is regulated by the growth of the shoot as a whole. On page 24, *Galium*, *Hippuris*, *Elodea*, *Ruppia*, *Cymodocea*, *Posidonia* and *Solanum* are incorrectly cited as examples of plants in which the foliage leaf originates in the outermost layer of the tunica. In discussing the "fundamental tissue systems" of the root (pp. 159-160) Dr. Engard appears to misapprehend completely the concept of Sachs' "Grundgewebe." It is perhaps unfortunate that this term has been rendered into English as "fundamental tissue" but there is no reason to believe that Sachs relegated this tissue-system "to a position of lesser ontogenetic importance than the epidermal or fascicular." At several points rather dogmatic statements occur which reflect Dr. Engard's lack of knowledge of certain modern literature. For example, on page 119 the statement is made that "knowledge of the structure of parenchyma has undergone little change since 1850." This is surely incorrect in view of the monographic treatments accorded parenchyma in Linsbauer's "Handbuch der Pflanzenanatomie" as well as the important studies of Lewis, Matzke, and Marvin on the shape of parenchymatous cells. In the reviewer's opinion, one of the most surprising statements in the monograph appears on page 123 where Dr. Engard expresses the conviction "that our present knowledge and terminology of vessels and tracheids has advanced little, if at all, beyond the stage at which DeBary left them." It is evident that this opinion would not have been expressed if Dr. Engard were familiar with the published investigations of Bailey, Frost, Tippe, Cheadle, Esau, and others.

With respect to the interpretation of his results, Dr. Engard arrives at certain conclusions to which the reviewer must take exception. An outstanding example is his view that the annular thickenings in the tracheary elements of the protoxylem are exclusively the result of the stretching and ultimate rupture of an original spiral band "and the consequent retraction of the ends of the segments to form a ring" (p. 131). That spiral bands are stretched and broken during the phase of internodal extension cannot be doubted. But that the annular thickenings in *Rubus* and elsewhere arise *secondarily* by the physical rupture of a spiral layer of secondary wall is highly improbable and is not supported by the ontogenetic studies which have been made on tracheary elements. The existence of several intergrading types of secondary wall pattern in a single tracheary element is a well-known fact and cannot be used to demonstrate the "ontogenetic origin" of annular thickenings. On page 164 it is stated with reference to root-histogenesis that "the protoderm, characterized by anticlinal divisions only, will become the two-layered epidermis." Evidence in support of this paradoxical conclusion is given neither in the text nor in the cited illustrations.

In the last chapter of his book, Dr. Engard seeks the answer to a fundamental question, viz., "What is the true status of cauline appendages—are they all homologous or are they *organa sui generis*?" By approaching this question from a developmental-physiological standpoint, an effort is made to reconcile the opposed ideas of Eames and Grégoire. The stem (with its diverse appendages) and the root (with organs of the same kind) are recognized as the basic morphological "units" of the modern plant. Furthermore, the stem is believed to consist of "two physiomorphological fields, the vegetative field and the reproductive field." A "field" is rather vaguely defined as the influence of the subadjacent axis tissue upon the developmental path which is early assumed by the appendage-primordium. Within the "vegetative field" are produced the cotyledons, cataphylls, foliage leaves and sepals while the "reproductive field" gives rise to petals, stamens and carpels. In *Rubus*, Dr. Engard regards the sepals as marking the "shift" or physiological transition between the two fields. While the appendages within each of the two fields are to be regarded as "*organa homologata*" among themselves, each group of organs are "*organa sui generis*" phylogenetically. In the reviewer's judgment, Dr. Engard's approach to the classical problem of homology indicates the need of further investigations along broad comparative lines. It is to be hoped that future studies will aid in clarifying the still perplexing question of the nature of the flower in angiosperms.—ADRIANCE S. FOSTER, University of California.

AN INTRODUCTION TO POLLEN ANALYSIS. By G. Erdtman, foreword by R. P. Wodehouse. Volume XII of New Series Plant Science Books; Chronica Botanica Co., Waltham, Mass.; G. E. Stechert and Co., New York City, 1943. 239 pp., 28 plates, 3 portrait plates, 15 text figs. \$5.00.

The science of pollen analysis has long needed a comprehensive book analyzing and summarizing methods and results of peat and coal investigation. Dr. Erdtman's *Introduction to Pollen Analysis* serves this purpose well. It achieves the distinction of being the first book in a comparatively new field, and although other books of similar subject will undoubtedly follow, this pioneer accomplishment is a worthy leader.

The introduction contains a brief historical review of the problems and attainments of continental European workers in the field of pollen statistics. The historical picture, however, is incomplete, since recent work is not included.

The chemistry of peat is considered in Chapter 2, which was contributed by Dr. H. Erdtman. Here special attention is given to the preservation of pollen and spores in peat.

The following two chapters are devoted to the preparation of fresh pollen and of fossil-bearing materials. They comprise the first fairly complete treatment in English of micropaleobotanical methods, although several procedures are given in their original German version.

The next six chapters deal with pollen and spore morphology. These are well written and clearly illustrated with the author's drawings. The clarity of the illustrations indicates a remarkable understanding of diagnostic features as they appear in fossil pollen and spores. Included are a useful terminology and glossary which should be of real value in developing a standard vocabulary for use by all paleobotanists.

Chapter 11 deals with the graphic presentation of pollen analyses. The type suggested for adoption is a line graph, with the pollen of each genus represented by a line and symbol. Although such illustrations are used by many Europeans, graphs of this type are frequently difficult to comprehend because of the possible confusion of detail. Of the several examples given, one diagram illustrating a study made by the author of peat collected in Itasca State Park, Minnesota, is misleading if the reader interprets the graph to indicate more than an illustration of a method of graphic representation. This particular graph is based on an incomplete peat section and must not be regarded as the complete pollen spectrum of the region.

In chapters 12-15 the problems of correlation of pollen spectra, output and dissemination of pollen, surface samples, and pollen flora of peat samples are treated. They contain not only a well-balanced discussion of the many problems, but also ample references to literature, should the reader wish to pursue the subject further.

A short, helpful chapter is devoted to a geographic survey of pollen statistical investigations. Since no publications later than 1939 are included in this survey, a second list which contains some of the most recent studies is found at the end of the book.

A brief discussion of Tertiary fossil spores and pollen is also included. To appreciate fully the history of modern vegetation greater knowledge of Tertiary floras will be necessary. Although there are several lines of approach to increase this knowledge, the micropaleontology of the extensive brown coal deposits promises to be a very important one. Dr. Erdtman has compiled a useful list of plants that have been identified from Tertiary rocks by spore and pollen analyses. However, some of the plants included in the list are regarded as problematic. The nomenclature of fossil pollen and spores is beset with difficulties not easily solved, since great similarity exists between some forms, and also, since extinct plants become more abundant with increased age of deposits. Many extinct spores and pollen will never be definitely associated with the species of plants from which they came. Where many such forms exist, they must be treated with taxonomic foresight. Various methods of treatment are briefly given in Chapter 17. Though Ibrahim's divisions of the genus *Sporites* R. Potonié 1893 are no longer recognized by most American paleobotanists, the author suggests a similar procedure for the unassigned pollen of pre-Quaternary deposits. This suggestion supplements Wodehouse's system of assigning any pollen form to its closest known group, i.e., family,

genus, species. In deposits of earlier than Quaternary time many extinct forms are encountered that cannot satisfactorily be placed within any known plant family. For forms of this sort, Dr. Erdtman proposes the following system: for grains united in tetrads the generic name, *Tetradopites*, grains in dyads, *Dyadopites*, grains without furrows and pores, *Acolpites*, grains with one furrow, *Monocolpites*, grains with two to many furrows, *Di-*, *Tri-*, *Tetra-*, *Hexa-*, and *Polycolpites*, etc., grains with pores, *Mono-*, *Di-*, *Tri-*, *Tetra-*, *Hexa-*, and *Polyporipites*, etc. Though this classification is artificial and many of the names are lengthy and difficult to pronounce, the system has the advantage of making many now undescribed pollen grains available for stratigraphic purposes. Unlike Ibrahim's segregation of *Sporites*, pollen grains are microspores and therefore the proposed system is not burdened with the problems of heterospory. Also, Ibrahim's generic segregates are partially based upon ornamentation such as reticulation, granulation, etc., which are not as fundamental characters as those used in Erdtman's suggested system. It should be pointed out that at present Erdtman's genera are not valid until full descriptions are published for each.

The last chapter describes the use of pollen analysis in the study of honey and drug problems. Though extremely brief, it introduces the reader to a most interesting field of pure and applied science.

Fortunately, errors in the book are few. One that may cause some confusion to the beginner is the citation (p. 33) to the chlorination procedure. Instead of appearing on page 28, this reference is given near the top of page 29.

Portraits of E. J. Lennart von Post, Nils Gustaf Lagerheim, and N. O. Holst are included. These are of special value to the peat scientist who is also interested in the men largely responsible for the development of his chosen science. A delightful caricature of the author at the end of the book shows him as a musician.

Dr. Erdtman's book will be read and reread by both beginners and advanced students of pollen and spores. Its style is lively and concise. Some readers may wish that the author might have given more space to certain chapters, but they will also realize that this book made its appearance under trying wartime conditions. Though prevented from keeping in close contact with the outside world and incorporating many recent advances in pollen analysis made in the New World, the author nevertheless succeeded in citing much of that literature.—L. R. WILSON, Coe College, Cedar Rapids, Iowa.

MANUAL OF HUMAN PROTOZOA. By Richard R. Kudo. Charles C. Thomas, Springfield, Illinois. 1944. 125 pp., 29 figs. \$2.00.

This manual is designed for the detection, preparation, and identification of the common intestinal Protozoa of man and makes no pretense of being a textbook of protozoology. It represents another response to the awakening of America to the importance of animal parasites which constitute serious problems in the field of tropical medicine. The organisms are divided into those parasitic 1) in the digestive tract, 2) in the circulatory system, and 3) in the muscles and reproductive system. Each species is dealt with separately and with consideration in regard to the trophozoites, precystic forms and cysts when present in the life cycles. Essential diagnostic characteristics are given with the simplicity and clarity which only a competent protozoologist can provide. The accompanying figures are original or modified, generously provided, and done with great exactness and care. Standard and dependable keys together with tables of differential diagnoses for each of the taxonomic categories of parasitic Protozoa of man, are provided to minimize the possibility of error. Users of this manual will find the methods of preparation standard and indispensable to a study of this group of organisms. This publication will undoubtedly prove of inestimable value not only to those individuals interested and actively engaged in the realm of tropical medicine but also to students and instructors charged with the acquisition and teaching of information relative to this field of endeavor. It is a pleasure to recommend this volume to zoologists, medical technicians, and physicians, alike.—J. D. MIZELLE.

INDEX FOSSILS OF NORTH AMERICA. By Hervey W. Shimer and Robert R. Shrock. (Chapters on Foraminifera by Joseph A. Cushman, Lloyd G. Henbest, and W. Storrs Cole; Crinoidea by Raymond C. Moore and Lowell R. Laudon; Brachiopoda by G. Arthur Cooper; Arthropoda by Frank M. Carpenter; Charophyta by Raymond E. Peck; and Calcareous Algae by Harlan Johnson). John Wiley and Sons, New York. (A Publication of the Technology Press, Massachusetts Institute of Technology). 8 x 13 inches, ix+837 pp., 303 pls. (8400 illustrations). Cloth, \$20.

This "new work based on a complete revision and reillustration of Grabau and Shimer's 'North American Index Fossils'" (1910) is quite the most impressive American work in invertebrate paleontology since the era of the great monographs. As a cooperative enterprise it resembles the Eastman translation (1913) of the Zittel Textbook, which it will partially replace. Undoubtedly, American paleontologists, to whom the work is dedicated, will for many years to come lean heavily on Shimer and Shrock's revision.

Some 7500 species are considered in the new work, so distributed as to give a fuller representation of genera than the prototype. In order to contain so many data in so few pages, the text has been cut to the bone of bare adequacy as accompaniment for the thousands of splendid illustrations. Both plates and descriptions are arranged chronologically, with only that part of the superstructure of classification convenient to the scheme. Species are the mainstay of the volume, as always in works dealing with stratigraphic indices, despite the avowed intention to emphasize genera. Genotypes are cited throughout the work, but too few of them, even when American, are illustrated on the plates, if genera are to be considered as basically indicial. In the original work emphasis was on stratigraphic systems and their major serial or subserial divisions. This seems still to be the main objective, and it might be debated if the enormous increase in number of species can be justified therefore. For readiest use, the fewest possible, commonly occurring guides should be the objective. Each inclusion should be most critically weighed for its stratigraphic value, and indices for as many stratigraphic categories as possible for each system should be selected. A substitute procedure would entail the inclusion of virtually every species of fossil, since each is in some degree or other an index. Rigorous exclusion should be the rule in the compilation of index guides. Many sections of the new work seem to have been prepared without proper weighing and choosing, and as a consequence are at once redundant and inadequate in terms of the strict purpose of the enterprise. Similarly, a treatise on diagnostic fossils is no place for synoptic glimpses or the inclusions of great rarities for mere systematic completeness. A case in point is the chapter on Crinoidea. It is a wonderfully fine boon to paleontology to have Moore and Laudon's revision of Paleozoic crinoids, but the frequency of crinoid occurrence in all but most extraordinary instances is such as to make it questionable if so much space should have been devoted to them in a general work of this nature. In other sections of the work species are noted which are known only from the holotype or the original collection.

No doubt the criticism will be raised that the new work, even as its predecessor, unduly stresses the eastern Paleozoic at the expense of adequate treatment of the Cenozoic, especially. In a compendium of 7500 species one might expect to find indices to most of the well-known classical stratigraphic units, even down to and including members. As a corollary, he might justifiably expect that any highly restricted indices included in the work would carry exact range data. Unfortunately, on both scores the present tome is remiss. We find almost a plethora of indices to the systems, series and subseries, and too few diagnostics to lesser stratigraphic categories. An occasional species of very limited range is given as a long-ranging index.

In order to make a fair sampling of the new work I have taken occasion to check it against the University of Cincinnati Museum's lists of the *described* and *published* species occurring in the classical Ordovician faunas of the immediate vicinity of Cincinnati. I find in the opus that guides to the Ordovician and the Upper Ordovician (Cincinnati) are legion, and seemingly in excess of the requirements. Eden, Maysville and

Richmond (sub-series or formational) guides are many and fairly satisfactory, but in the subsidiary necessities of either a stratigraphic specialist or an amateur collector the work is notably deficient. The species data on the Covington subseries at Cincinnati are given below.

	Cincinnati Lists		North American Index Fossils		
	1. Complete fauna	2. Of list 1, index species	3. Of list 1, includes	4. Of list 2 includes	5. Of list 4, shows the same range as list 2.
<i>Members</i>					
Maysville fm.					
Mt. Auburn	53	3	18	0	-
Corryville	146	70	23	4	1
Bellevue	92	22	29	4	0
Fairmount	199	103	42	14	6
Mt. Hope	84	10	27	1	0
Eden fm.					
McMicken	106	11	30	1	0
Southgate	131	37	34	8	6
Economy	152	54	30	1	0
Fulton	45	16	13	5	3

Several features of the original work are omitted in the new one. Other publications of recent date make a stratigraphic summary unnecessary. However, the faunal lists of the former edition have always been useful and might well have been brought up to date and included in the present work. The authors have wisely omitted the space-consuming artificial keys. Unless such keys are designed for complete synopses or entire faunas, and are accommodated to the varying aspects of fossil materials, they are valueless except as morphologic summaries,—and this was not their intention in the former edition. Several other aspects of the first edition have been left out with the obvious change of objective from amateur to professional. Whereas the original work was manifestly to be employed by non-specialists and amateurs, the new work is of a more technical and specialized character, apparently produced with the technician and researcher in mind.

Since the keynote of the work is utility, any minor inconveniences are important. Under this head comes the lack of geologic data on the plate descriptions. It would also have been a great convenience to have had the genera numbered in sequence and a cross reference to this number given on the plate analysis. In lieu of this a page notation for each species on the plate descriptions would have been helpful.

There is no question of the monumental importance of the new *Index Fossils* for practicing geologists and paleontologists. It is, however, a selection for a specific function, and for critical employment. It is hardly to be recommended for the use of the non-specialist. Its necessary incompleteness makes it a potentially dangerous and at least exasperating tool for the amateur, especially for the one who is primarily concerned with identifying localized collections, or accurately locating himself in his geologic section.

It is easy to carp from the side-lines,—but any criticisms which arise are minor matters in comparison with the paean which the work, the authors and their collaborators deserve. It requires heroic determination to see so arduous a task through to so eminently satisfying a conclusion.—KENNETH E. CASTER, University of Cincinnati.

in
the
ere

ma
ge

ns
of
le
ng
as,
ss
li-
ge
to
nd
d.

at.
so
ns
or

or
e-
ne
ast
th

or
rs
ly